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Editorial: We're All Chemicals — Inside Front Cover

25¢

We're All Chemicals

➤ THE NUMBER of things making up the world is increasing at a breath-taking rate. As unfamiliar elements are coming into use, their compounds add to the list of materials with special properties, good for new purposes. Organic compounds of the familiar paraffin series are augmented by the ethylene series with its double bond and the acetylene series with its triple bond, which in turn polymerize to increase the already long list of plastic materials. Non-metallic elements join these series to parallel them with new lines like the silicones and the fluorocarbons. Each new product has its own individuality. Each holds the possibility that it will find a new use or solve an old dilemma.

It is perhaps inevitable, in this state of affairs, that the advertising pages teem with "special ingredients." Every copywriter vows that his product contains one, which will lubricate your car—clean your teeth—bleach your clothes—add a new flavor to your whiskey. Every wonderful property is described as "due to a chemical," a category that describes everything in the world, including ourselves.

It is not only the advertisements for "mass circulation" reading that deal in mystery. Too often technical announcements are so vague about details that they bring out the thought: Is it possible that the people who wrote this know no more about the product than "it's a chemical—very technical—you wouldn't understand it if I told you (so why should I bother to learn it myself?)"

As the world absorbs more technically produced materials, it will become more important that people learn exactly which textiles will be cooked by a hot iron, which plastics will soften to a gooey mess with which cleaning fluids, which metals will have their polish ruined by which scouring powders, and, conversely, which materials will keep their lovely sheen with what kind of care. The only way the chemist himself can keep this kind of information straight is by exact nomenclature, based on thorough knowledge.

Therefore, let's have more chemical training, not only for research but for living in our chemical world. Ad-writers, salesmen, clerks and stenographers who can handle the technical vocabulary would be an improvement in many a business organization.

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▸ THIN SHEETS *of polyethylene plastic are transparent when touching the object they cover, more translucent at a distance. Impervious to liquids and not easily torn, the film lends itself to novel packaging.*

Strange New Plastic

by MARTHA G. MORROW

▸ POLYETHYLENE, one of the newest of the plastics, is also one of the strangest:

Dishes of this gas-derived resin float on the sudsy water in which they are to be washed.

Few chemicals affect it, and even those in which it will dissolve must be heated before they act as a solvent.

Thin films of the plastic are soft and pliable, thick slabs of it are tough and horny.

Plates, cups and ice box dishes that are tasteless, odorless and unbreakable are made from polyethylene. Films of it provide packaging material for both commercial and home use. Bottles, tops, materials for shoes and handbags, and even drain pipes are created from this unique plastic.

As early as 1933 it was known that

ethylene, used for anesthetics and to hasten the ripening of fruit and vegetables, could be polymerized, that is, linked together in long chains to form a resinous material. After pilot plant trials for several years, commercial quantities were first produced in the United States six years ago. Most of the early production of polyethylene was used to insulate high-frequency wire and cable, so essential to the war effort.

This new material is made from ethylene at high temperatures and high pressures. Composed of long chains of hydrocarbon groups consisting of carbon atoms combined with twice as many hydrogen atoms, polyethylene shows great promise as a versatile plastic.

Large pipes of polyethylene carry hot nitric acid in atomic energy plants, while tiny tubes of the plastic have been used to control bleeding stomach ulcers.

Bottles of polyethylene are strong enough to transport liquids great distances and under rough conditions, yet flexible enough for the containers to be used as atomizers upon reaching their destination.

During 1948, approximately 15,000,000 pounds of polyethylene were produced in this country. About 6,000,000 pounds were made into film for packaging everything from garden soil to frozen foods. This year Bakelite and duPont expect to more than triple production of this raw material so that an estimated 20,000,000 pounds will be used for film, an equal quantity for coating wire destined for television, radio and electronic applications, and another 8,000,000 or so for molded cups, plates and containers.

Polyethylene is the lightest of the plastics. It weighs less than an equal quantity of water, its specific gravity being .92. Thus pellets of the plastic float on water and even a polyethylene tumbler filled with water does not sink to the bottom.

It softens at a temperature a little below that of boiling water, and, therefore, dishes made of it should not be placed in boiling water. They may, however, be rinsed in very hot water (170 to 180 degrees Fahrenheit) without harm.

One of the outstanding characteristics of polyethylene is its chemical inertness. Few materials mar the good looks of its satiny surface. It is insoluble in all organic solvents at normal room temperature.

Vinegar, lemon juice and acetone, if left on the plastic, leave no mark or stain when wiped off. The plastic does dissolve in carbon tetrachloride (frequently used as a household cleaning fluid), but this material must be heated to about 140 degrees Fahrenheit to be effective.

This chemical inertness of polyethylene makes it more difficult to seal pieces together with a solvent than with heat. Thin films are usually sealed with a hot iron or similar equipment; thick pieces are welded together by using gas-welding equipment or hot air.

One of the advantages of polyethylene, on the other hand, is its inherent flexibility; thus no plasticizer need be used. The resin merely is heated, then molded into cups or extruded into thin films.

Impermeability to all but a very few liquids and gases, plus the fact that it is odorless and tasteless, is

▸ POLYETHYLENE *finds many uses in food handling techniques, as it is free from taste or odor and does not readily acquire them. This pastry sheet gives the housewife a pattern to roll pie crust the right size for the pan.*

largely responsible for the success of polyethylene film.

Its uses range from washers for your sink or washbowl to disposable bottles for baby's milk to liners for drums in which chemicals are shipped.

A novelty woven fabric is being made from polyethylene. This material, developed specially for shoes and handbags, is made by slitting thin film into ribbons, folding it, and then weaving it into cloth with a pack weave. One of the advantages of this type of cloth over other plastic cloth is that it has enough body to hold its shape, while still retaining its flexibility.

Circular tubing as well as flat films of polyethylene are popular. Such tubing has transparent walls only .001 to .004 inch thick. Miles and miles of this tubing are made by forcing the hot plastic through a narrow circular opening. The tubes can be heat-sealed where desired, producing long or short bags without seams.

Thin films of polyethylene are also being used to protect paper, cloth and

➤ SQUEEZABLE BOTTLE *is its own atomizer. Thick polyethylene forms this container for liquid products such as deodorants and nose drops.*

metal. A coating only .0015 inch thick, for instance, converts shelf paper into a washable article giving long service.

This very thin coating can be applied either to paper or cloth in two ways. It can be put on by knives that place a fine layer on the material as it passes beneath them. Or an extremely thin polyethylene film can be laminated to the paper or cloth with an adhesive.

By either of these methods, however, 15 pounds of polyethylene will coat 3,000 square feet with a layer .0015 inch thick. That means the coating is about one-half as thick as the page you are now reading. Thin as this layer is, it provides all the necessary protection to the underlying cloth or paper.

In general, polyethylene resins are fabricated in almost exactly the same manner and in many of the same types of machinery as other thermoplastic materials. The principal differences between this and other plastics is that polyethylene softens and becomes quite fluid at a lower temperature. On the other hand, it can be molded at extremely high temperatures.

At the higher temperatures, however, shrinkage becomes a problem. Thus, in the molding of polyethylene, dies must be designed to allow for the material to shrink as much as 4% as it cools, although other adjustments can reduce this to as little as 2½%. Thick sections also require special cooling techniques to avoid the formation of voids or bubbles in the center.

Films of polyethylene are outstanding for their folding resistance. They may be creased, yet readily spring back into shape when released. Also these films do not become brittle upon long exposure to freezing and below-freezing temperatures. They have a soft, warm and somewhat waxy feel. Thick sections of the plastic bounce when dropped.

Polyethylene is highly transparent in thin layers immediately over an object, but it is translucent when thick. It naturally is colorless, with a "frosty" appearance. Dyes and pigments may be added, however, to produce a wide variety of colors.

Polyethylene, like many other plastics, is produced in a variety of grades, each with different physical proper-

ties. In some grades, many more atoms of hydrogen and carbon — but always the same proportion of two atoms of hydrogen to one of carbon — are linked together to form each molecule of polyethylene than in others. Thus some have a much higher molecular weight than others.

Polyethylene of very low molecular weight is a grease or wax; that of medium molecular weight is a soft wax-like resin; and that of very high molecular weight, the kind used in articles being sold now, is tough and horny. In all cases, however, the molecules are formed of carbon atoms joined together to form long chains, always characterized by a double bond between two of the carbon atoms.

On the Back Cover

➤ POLYETHYLENE FILM *as the electron microscope sees it. The magnification is indicated by the 1-micron mark on the picture. If you would like to examine bits of polyethylene products in various forms, turn to page 48 for the sample kit announcement.*

Radioactive Silk Spun

➤ RADIOACTIVE silk has been spun by two moth larvae.

Interest centered not in silk as a fiber or fabric but in silk as a chemical compound, it is explained. Silk consists largely of a protein called fibroin, which can be used in research as typical of all protein, which may be considered the chemical basis of life itself. Hence the interest in getting a radioactive "tag" attached to it, for purposes of identification in various stages of its chemical life-history.

The silk was spun by the caterpillars of the big Cecropia moth, one of the first natural-history objects collected by most children. Small amounts of two amino acids, glycine and alanine, "tagged" with radioactive carbon 14, were injected into the two fat larvae. About 24 hours later they started to spin their cocoons.

Radioactivity of the silk in these cocoons was proved in three ways: by the ticking of a Geiger-Muller counter, by photographic "autographs" left by fibers and clipped bits of silk placed in contact with camera film, and by elaborate chemical analysis.

The silk-spinning glands were dissected out of two other caterpillars and kept for several hours in a solution containing the radioactive carbon. Subsequent analysis of their proteins also showed the presence of radioactive silk substance.

These experiments were performed by Drs. Paul C. Zamecnik, Robert B. Loftfield, Mary L. Stephenson and Carroll M. Williams, of the Collis P. Huntington Memorial Hospital and Harvard University.

All Three Food Classes Supplied by Chlorella

Food of the Future From Algae

➤ FOOD-PRODUCING possibilities of a lower plant that can treble its bulk in 24 hours if supplied with constant illumination are being explored as a possibility for extending the world's supply of crops.

The plant is the one-celled alga known to botanists as Chlorella. It is familiar as the cause of much of the green scum that forms on cattle ponds and other bodies of still water in warm weather.

First hint of the possibilities of this humble plant was obtained by plant scientists of the Carnegie Institution of Washington. They discovered that by controlling its chemical environment they could at will cause it to produce a very high yield of either protein or fat.

The Stanford Research Institute, Palo Alto, California, has been asked to probe into the economic potentialities of Chlorella. One of the first things they discovered was that it could be made to grow very much more rapidly by giving it 100 times as much carbon dioxide as occurs naturally in the air. This extra supply is readily obtainable from the waste gases from brewery vats or from the combustion gases escaping up factory chimneys.

The Institute has also undertaken a study of the fat or oil piled up in Chlorella's tiny body when its nitrogen supply is kept short. This may prove useful in soapmaking or similar industries, thereby releasing animal or vegetable fats and oils now used there for other purposes. It is even possible that Chlorella oil may prove a good drying oil, which is always in demand by paint and varnish makers.

Chlorella protein, which accumulates when the plant is given an abundant supply of fixed nitrogen, is most likely to get into the human food cycle by way of livestock or poultry feed, being converted into milk, meat and eggs. There is the possibility, however, that this protein may be processed into a form palatable enough for direct human consumption.

Algae are plant forms such as seaweed, sea lettuce, ferns, and pond scums. They often have stem-like or leaf-like parts, but do not have true stems or leaves. They range in size from the microscopic cells that color the red snow sometimes observed in polar and alpine regions, to giant kelp with broad fronds, often extending more than 600 feet from their holdfast on the bottom of the sea.

Chlorella, the kind of algae now being considered as a food source, is a green, single-celled fresh water genus. The Emerson strain of Chlorella was selected for this work, because it is pure and very hardy, and is known to have rapid growth rates. For these reasons, it has been used for years in studies on algae.

In the past, however, it was believed that the growth of algae was independent of environment, as far as chemical composition was concerned. Then Dr. H. A. Spoehr and Dr. Harold W. Milner, at the Carnegie Institution on the Stanford University campus, made an exciting discovery. They found that Chlorella grown under certain conditions contained as high as 75 to 85 per cent fat—as much as butter. Even more significant, they learned that Chlorella grown under certain other conditions contained as much as 50% protein.

Research Corporation became interested in the development, and asked the Stanford Research Institute to make a critical study and evaluation of all the information available on Chlorella, and to determine their possible use as a food, or as a source of chemicals.

The Institute analyzed the information on algae and found amazing possibilities. Certainly it was technically feasible to produce the substance on a large scale, but the economics of the system were unknown. Further studies of Chlorella culture on a larger production basis were then begun.

Chlorella cells are microscopic in size—about one ten-thousandth of an inch in diameter. Ten million of them compressed into a mass would be about the size of an ordinary grain of sand. They occur commonly in barnyard troughs, and account for the green murk of untended swimming pools. A lean cell in its native state has the distinctive green coloration of chlorophyll, while a cultured cell with high fat content tends to take on a pale amber hue.

The necessary environment for cultivation of Chlorella is made up of four elements; light, water, carbon dioxide, and certain mineral nutrients, including fixed nitrogen. Sunlight and water are cheap and abundant. Carbon dioxide is present in the air, but at much lower concentrations than is needed for efficient production. In laboratory experiments it has been found that aeration with 4.45 per cent carbon dioxide, which is one hundred times the incidence in natural air, provides a saturating concentration for photosynthesis—the means by which plant cells fix their carbohydrate structure. Natural carbon dioxide can be supplemented from the products of fermentation plants, or from stack gases. The needed mineral nutrients are usually present in water, but several inexpensive salts must be added. The nitrogen is available from nitrogen-fixing plants, which obtain it from the atmosphere.

The fixed nitrogen concentration controls the chemical composition of the Chlorella. When a great deal of fixed nitrogen is present, the algae grow with a high protein content. If fixed nitrogen is very low in the environment, a high fat content is produced in the Chlorella. But there is often a great difference between producing results in a test tube, and producing the same results in a factory—between what is possible, and what is practical. Applied research provides the machinery needed to bridge the gap between the basic discoveries of fundamental research, and products and processes of commercial value.

Foremost among the many problems to be worked out, before

Chlorella can make a contribution to the world's food supply, is determination of the exact cost of production. If the economics are sufficiently attractive, there are three possible ways in which Chlorella could affect the food problem. First Chlorella may prove to be a good source for certain chemicals, such as fats and oils, which are used in the chemical industry. This would enable us to convert present sources of these chemicals to food production.

Or, the algae may provide food for livestock. This would release arable land for the production of food for human consumption, and would permit the increase of flock and herd size, thus adding to the meat supply.

For the third, the products of Chlorella may be suitable food for humans. Up to now, little analytical work has been done on Chlorella, except for determining the quantities of fat, carbohydrate, and protein present. In many ways, some of the fat fraction is similar to drying oils, such as fish oils or linseed oil. Further analytical work should indicate whether it is suitable for use as a drying oil, whether other useful chemicals are present, and whether the algae are a source of vitamins.

The chemical content of Chlorella indicates that they should have a substantial nutritive value, but much more study is necessary before this can be accepted as established. What algae will taste like is still unknown, but it is probable that they will have to be processed to render them palatable. Probably some important dietary elements are missing from Chlorella, as they are from most foods; if so, what these elements are must be determined.

It will then still be necessary to work out many technical and economic problems involved in the cultivation of algae. Rates of growth under different conditions must be studied to determine what the best conditions for growth will be. The structure of a plant to make the best use of the sun's energy is being worked out. Labor, processing, energy supply, and other cost factors are being investigated.

On all sides today, warnings are heard about the growing problem of finding food for the peoples of the earth. Not only are there already large areas where hunger, and even starvation, exist; but the over-all population of the world is increasing much more rapidly than our ability to produce food. The situation offers a challenge for we have by not means exhausted the resources which nature has placed at our disposal. Almost all the energy man consumes, in food or fuel, comes originally from the sun. Yet he uses only a small proportion of the sun's energy available to him daily.

If the total area of the United States were divided equally among all the people living here, there would be about 14 acres of land for each person. On these 14 acres fall daily roughly 2,000 times more energy from the sun than one person consumes. The proportion is perhaps even higher, because a large part of the energy we use is not from our daily supply, but is accumulated over many months, in the form of plant and animal life, or over many centuries, in the form of coal, oil and other fuels.

If we could make efficient use of the energy available to us every day, this country could support 2,000 times its present population. But we can't. The foods produced on agricultural lands today make very inefficient use of the sun's energy; in fact, the greatest efficiency of any food plant known is only about ⅛ of one per cent.

Algae, it appears, may attain many times the efficiency of other food plants in the conversion of sunlight to food. Moreover, this potential new kind of food is one that could be produced under carefully controlled conditions, and would not be at the mercy of the weather, as are conventional food crops.

Strange Future Foods

➤ FUTURE POPULATIONS of the world, that otherwise may be hungry, may learn to eat yeast, seaweed, algae and wood. At a recent United Nations conference on conservation and utilization of resources at Lake Success there was discussion on just how soon and by what methods such "creatable resources" can be turned to practical use.

A most promising discovery is that a special microorganism, called Rhodotorula gracilis or, more simply, fat yeast, produces in its cells a substance that is 50% to 60% fat. Because fat is one of the foods in shortest supply, this excites practical-minded technologists. The kinds of fatty acids in the yeast fat are rather close to palm oil fat. The yeast fat also contains some of the vitamin B complex and the stuff from which vitamins A and D are made. A hundred pounds of sugar fed to this yeast produces 16.5 pounds of fat, as well as a quarter that amount of protein. The sugar used can be in molasses of the lowest grade.

A report by Dr. Harry Lundin of Sweden's Royal Institute of Technology, Stockholm, shows that the dry matter in fat yeast costs about 13 cents a pound and that a desirable mixture of fat and protein should be manufactured by a practical continuous process. First the yeast is allowed to grow for 10 hours with a moderate amount of fat in its cells. Then it is put through a fattening phase for two days when it converts the sugar to fat at a great rate.

Britain turned to yeast for possible cattle feeding when a Nazi blockade threatened in 1940 just as the hard-pressed Kaiser's government in 1915 studied yeast manufacture from inorganic nitrogen. This was revealed by Dr. A. C. Thaysen, who reported from Britain's Colonial Microbiological Research Institute at Trinidad. Since 1944 there has been in Jamaica a successful food yeast factory, producing material suitable for human consumption.

The yeast itself can be fed on sugar made from wood, Dr. J. A. Hall of the U. S. Forest Service at Portland, Ore., reported. Or molasses made from wood can be fed directly to livestock, as shown in many U. S. agricultural college tests.

As for seaweed, used for centuries as laver bread fried for breakfast in the case of the reddish or sea lettuce sort in Scotland, Dr. F. N. Woodward, director of the Scottish Seaweed Research Association, predicted that the greatest use of marine algae will be in providing raw chemical materials, including alginic acid now used in food, drugs and cosmetics.

Students Should Learn Probability Techniques

Test Experiments by Laws of Chance

➤ SCIENCE should take a tip from the gambling fraternity and apply the laws of chance to speeding up research progress, chemistry teachers at the American Chemical Society's national meeting were told by Dr. W. L. Gore of the Plastics Department of E. I. du Pont de Nemours and Company, Arlington, N. J.

Widespread use of "probability mathematics" is urgently needed because of the complexity of modern scientic investigations, but little can be accomplished along this line until more workers are trained in the field. Dr. Gore called upon educators to give greatly increased emphasis to the application of statistical methods to experimental problems, and to provide courses in the subject.

The way in which the rules of probability are used by the research scientist has nothing to do with so-called "chance" discoveries, the speaker pointed out. Instead, he explained, the method consists in applying the fundamental philosophy of probability to laboratory investigations in such a way as to avoid unnecessary experimental work. Carrying out the minimum number of experiments needed to establish a particular scientific fact quite obviously results in greater laboratory efficiency, he believes.

It is not necessary for the novice at "crap-shooting" to roll dice a thousand times before he learns that seven turns up more frequently than any other number, nor does it require a thousand hands of poker to establish the fact that drawing to an "inside straight" does not, as a rule, pay off.

The use of probability statistics in scientific work involves essentially the same principles as are employed in calculating the probability of winning in any game of chance, although the situation in scientific research is much more complicated.

By applying probability considerations to scientific experimentation in the laboratory, the chemist versed in the statistics of probability knows just how many experiments are needed to transform a theory or hypothesis into an established fact with a reasonable degree of certainty. And that is a major objective of laboratory experimentation.

The use of probability methods in the laboratory does not help during the "flash of genius" stage of a scientific undertaking, or with the generation of a hypothesis. That is a function of the creative imagination. But when the hypothesis is to be tested by the fires of experiment, statistical methods should be employed to assist in designing the experiments, to reduce to a minimum the amount of experimental data which must be calculated, and to bring probability estimates to bear on the decision as to whether or not the hypothesis is substantiated by the experimental results.

Scientific Cold
Far Below Zero

How Cold is Cold?

by A. C. MONAHAN

▶How COLD is cold? Scientific cold is neither the zero weather that drives a New York population indoors nor the occasional 60 below in Montana that even toughened ranchers find hard to stand. It is a temperature nearly twice as far below zero on the Fahrenheit thermometer scale as the boiling point of water is above.

Laboratory scientists produce and work with cold nearly 460 degrees below the ordinary zero. In theory the lowest possible temperature is within a fraction of a degree of minus 460, and for this reason it is called absolute zero, a no-heat spot where no heat remains in any substance.

One reason scientists are interested in achieving such extremely low temperatures is because of the strange behavior of metals and other substances in the absolute zero region. Practical applications will undoubtedly follow their research findings.

Everybody knows that there are temperatures far below the ordinary zero of the thermometer. Perhaps they realize also that there must be a spot below which temperatures cannot go. This absolute zero is the spot. It is close to minus 460 degrees on the Fahrenheit scale or minus 273 degrees on the Centigrade. It is the temperature at which the molecules in any substance are at complete rest.

Absolute zero has never been reached, and never will be, but scientists have got within a degree of it. There is molecular motion in all matter that contains any heat. The molecules and atoms of which matter is composed are in constant motion. The higher the temperature, the more rapid the motion. At very, very low temperatures, however, the movement is so sluggish that the molecules have practically no motion. Absolute zero is the temperature where they would have no motion whatever. As the scientists would express it, absolute zero is where the molecules are free of thermal disturbance.

One particular property of some metals at temperatures in the absolute zero region is their sudden loss of resistance to passage of an electrical current. Because of this, scientists say they possess superconductivity. In one famous experiment, an electric current was set up and continued to flow in a ring of lead metal as long as it was kept within ten degrees of absolute zero.

Scientists are searching for ways to use this superconductivity. One possibility is using it to improve the sensitivity of electronic receiver circuits. Actually, superconductivity has been put to work in a limited way. This is in a sensitive heat measurer known as a bolometer. This heat-detecting device, built around a superconducting responsive element, can be used to detect heat waves from invisible smoke stacks of warships and from the exhausts of airplanes.

➤ POWERFUL MAGNETS *are used at the U. S. Naval Research Laboratory to explore the region within one-thousandth of one degree of absolute zero.*

The initial interest in very low temperatures was created chiefly by the desire to liquefy such gases as nitrogen, oxygen, hydrogen and helium. Helium, the last to yield, was reduced to a liquid state in 1908 by a Dutch scientist.

Helium is the lighter-than-air, noncombustible gas that is extracted from natural gas in Texas by the United States government and used in American ballons and airships. It is also used in many other applications including medicine, and as a shield in arc-welding to prevent the metal being welded from oxidation.

Helium becomes a liquid at 456 degrees below zero. The liquid helium of two degrees above absolute zero conducts heat a thousand-fold better than copper. It has the highest thermal conductivity known to man. Liquid helium has no viscosity, and flows without drag. For this reason, it is called a superfluid.

It has been recently shown, however, that helium of mass four only reacts in this strange way. Helium of

▸ LIQUID HELIUM *is being transferred from the Collins liquefier to a Dewar container for study of reactions under intensely cold conditions, at the U. S. Naval Research Laboratory.*

mass three is relatively "normal."

Another interesting thing about liquid helium, cited as an example of the strange behavior of substances in the absolute zero range, is that it seems to exist in two forms, known as Helium I and Helium II (to be distinguished from the difference of mass). The second of these has many strange properties, including the ability to separate itself from the first by climbing up and over the walls of the container.

If not familiar with the word, add cryogenic to your science vocabulary. The first part of the word is from early Greek and means cold. Laboratories engaged in studies in the extremely low temperatures are known as cryogenic laboratories. There are at least a dozen in the United States and as many more in other countries. In Europe, they extend from England to behind the Iron Curtain. In fact, Russian scientists during the past decades have done valuable work in this low-temperature field.

Notable for developments in the cryogenic field is the U.S. Navy's Of-

fice of Naval Research. It is supporting very extensive research at more than a dozen university laboratories in the United States. These stretch from the Massachusetts Institute of Technology to the University of California. The National Bureau of Standards is also interested in the work, and has developed recently improved equipment by which helium is more easily converted into liquid form.

To get extreme low temperatures, high pressure and the escape of highly compressed gas are used. The device used in laboratories to produce the very, very low temperatures is known as a cryostat. One widely used is the Collins helium cryostat, named after its designer, Dr. Samuel C. Collins of the Massachusetts Institute of Technology. It is manufactured by Arthur D. Little, Inc., Cambridge, Mass. It employs helium as a working fluid.

It is a complicated machine, but it works somewhat like the ordinary electric refrigerator. Highly compressed gas is forced through a tiny jet. This cryostat, in addition, makes the helium gas used in it operate a piston-driven engine as means of cooling the gas.

The improved helium liquefier developed at the Bureau of Standards, which is working in co-operation with the Office of Naval Research, is based on what is known as the Simon principle. It differs from the ordinary Simon apparatus in that the liquid helium is delivered into an external receiver by means of a transfer siphon.

The heart of this new Scott apparatus, named after R. D. Scott of the Bureau staff, is a thick-walled monel chamber, designed to withstand a pressure of 4100 pounds per square inch, within which the helium is liquefied. Both are contained in an evacuated container, which is surrounded by liquid hydrogen. A combination of high pressure and escaping helium forms the liquid.

A practical application of low-temperature research is a tiny rocket motor, developed in the Cryogenic laboratory of the Ohio State University, that uses liquid hydrogen as a fuel and liquid oxygen as the oxidizing agent. Its exhaust jet nozzle emits gases at a speed of around 15,000 miles an hour, it is claimed.

Hydrogen is one of the most powerful chemical fuels known to science. When it is cooled to some 400 degrees below zero it becomes a liquid at atmospheric pressure. Oxygen is liquefied at a much higher temperature. Liquid oxygen, widely used in industry, requires a temperature of about minus 245 degrees to form. Other institutions are experimenting with liquid hydrogen as a fuel, but Ohio State claims the distinction of being the first to use it in a rocket motor.

Aluminum metaphosphate is used in making a glass that transmits a substantially greater amount of ultraviolet light than ordinary glass.

New strains of safflower developed in the United States yield as high as 34% oil, a satisfactory substitute for linseed as a drying oil in paints; safflower grows at rather high elevations and requires little rain.

Christmas Gift Books

by JEANNE L. HOPSON

There is no more thrilling Christmas present than a good book. Listed below are books which have come out within the last six months, which could serve as suitable Christmas gifts.

Popular Mechanics Money-Making Hobbies by the Editors of *Popular Mechanics* (160 p., illus., $2.00). A collection of 132 hobbies especially selected for extra-income possibilities. There are sections on plastics, leathers, ceramics, and gem collecting accompanied by helpful illustrations. The hobbies are also selected with an eye toward keeping expenses at a minimum.

The Conquest of Space by Chesley Bonestell and Willy Ley (*Viking*, 160 p., illus., $3.95). The authors take the reader on a journey through space to the planets and other heavenly bodies. Bonestell's paintings are extremely colorful imaginative projections of his concepts of what these places look like.

The Plant Alkaloids by Thomas Anderson Henry (*Blakiston*, 4th ed., 804 p., $14.00). A standard reference work covering the occurrence and distribution of these substances in plants; the biogenesis, or the methods by which alkaloids are produced in the course of plant metabolism; analysis; determination of structure and pharmacological action.

Electron Microscopy Technique and Applications by Ralph W. G. Wyckoff (*Interscience*, Approx. 250 p., illus., approx. $5.00) will be published sometime in the first few weeks of December. A monograph bringing together information for the understanding of this instrument and a survey of some of the applications already made of the electron microscope. A valuable bibliography is included.

Advanced Organic Chemistry by G. W. Wheland (*Wiley*, 2nd ed., 799 p., illus., $8.00). A unified treatment with emphasis on the structural theory in its broadest sense.

Metals Reference Book by Colin J. Smithells, Ed. (*Interscience*, 734 p., illus., $13.50). An immense amount of data brought together relating to the fields of metallurgy and metal physics. The style of presentation is similar to any handbook.

Titanium: Occurrence, Chemistry, Technology, by Jelks Barksdale (*Ronald*, 591 p., illus., $10.00). A compilation of much of the material in a systematic collection which forms a good basic working reference volume.

Francis Bacon by Benjamin Farrington (*Schuman*, 202 p., illus., $3.50) will be published November 30th. Written with the idea that to achieve progress today and in the future, we must know the past. The author's material is woven around Bacon's ideal that knowledge ought to bear fruit in words, that science ought to be applicable to industry, and that men ought to organize themselves as a sacred duty to improve and transform the conditions of life. This is volume 11 of Henry Schuman's Life of Science Library.

Solar Chemistry

From a new book, Our Sun, by Donald H. Menzel, published by Blakiston, $4.50.

➤ HERE ON the earth the atoms are moving at leisurely speeds. For example, a supermicroscope would show the molecules of our air traveling at average velocities of some 14 miles a minute. It may seem paradoxical to refer to such a speed as "leisurely." I use the term in the relative sense. In the sun's atmosphere, atoms move with velocities of from five to ten times greater than on earth. The difference, of course, is due to the higher temperature. As a matter of fact, the velocities themselves, or more exactly, the energies of the moving atoms determine the temperature. When we heat the water for coffee, we are merely imparting to the molecules greater speeds, greater energies. If we could speed them up by other means the temperature would rise accordingly.

If we could see the molecules of our atmosphere in motion, we should be astonished at the frequency of collisions between the particles. Moving at random, with no driver to guide them, the molecules hurl themselves recklessly at one another. Fortunately, the elastic cloud of electrons that surrounds each atomic nucleus acts as a very effective "bumper." Rarely does collision damage an air molecule. The particle bounces away and dashes off in some new path until another impact deflects it again. Each molecule of air in the course of a single second, collides about 10,000 million times!

At higher temperatures, however, the atoms and molecules, moving more rapidly, are not always so fortunate. Two automobiles, traveling at five miles an hour, may collide without damage. But increase the speed to fifty—and fenders fly in all directions. The energies increase with the square of velocity. A collision at fifty miles an hour is not ten times but a hundred times more serious than one at five miles an hour—a simple fact that the driving public seems not to appreciate fully.

On the face of the sun, the atoms will sometimes be dented, at other times broken, by the impacts. A hydrogen atom, hard hit by another atomic projectile, may change from its most common vibration pattern to some other type. Atoms, unlike automobiles, possess the ability to repair themselves. A fraction of a second later the atom sends out a quantum of radiation, and reverts to its initial stable form, ironing out the "dents."

Occasionally the crash is so terrific that the atom may lose its electron entirely. When this sort of catastrophe happens, the repair is not immediate. The atom, or rather the ion, must wander on until its encounters another free electron. And then the repair occurs automatically. Nor does a hydrogen atom have to worry about

the source of its new electron. Electrons are all alike; as spare parts they fit any atom.

Collisions are not the only means for denting and disrupting atoms. I have already indicated that radiation plays a similar role. An atom, absorbing and emitting light, changes from one vibrational pattern to another and back again. If the disturbing quantum has enough energy, i. e., if it has a sufficiently small wave length, it can ionize the atom. In the sun both processes are active. We see, in the spectrum, lines of both neutral and ionized atoms.

The spectrum of the sun is essentially "continuous," i. e., all colors of light are present, from the far ultraviolet through the visible rainbow band of color and on into the infrared. A careful examination, however, shows that certain colors are missing, some to greater degree than others. The entire spectrum is crossed by thousands of dark lines, termed the "Fraunhofer lines" after the discoverer. Some, called the "telluric lines," arise from absorption by various molecules of the earth's atmosphere. The sun's gaseous envelope is responsible for the remainder. We shall concern ourselves only with the latter.

The mode of origin of these lines was long a puzzle to astronomers. They clearly corresponded in position to the bright lines of the various chemical elements. Eventually, astronomers recognized that the missing radiations were "absorption lines;" the atoms in the cooler, outer layers of the star absorbed from the continuous radiation emanating from the lower depths the specific colors appropriate to the chemical nature of the various atoms.

We still do not understand completely how the continuous spectrum arises[1] Deep in the stellar interior, where the density is high, the crowded atoms jostle one another so violently that the atom rarely has a chance to assume the vibrational pattern characteristic of absorption-line formation. Most of the absorption and emission is produced by the flying electrons as they switch from one path to another, occasionally attaching themselves momentarily to some ion they happen to encounter.

The "crowded" condition of the sun's atmosphere arises not so much from the numbers of atoms as from the high speeds at which they are moving. A church, in which 500 people are sitting more or less quietly, may not seem crowded at all, whereas 50 couples "jitterbugging" on a dance floor of equal size may feel very cramped for room as they frequently collide with one another.

In standpoint of atomic population, the density of the solar atmosphere is far less than that of the earth's. Since the sun is gaseous throughout, the word "atmosphere" applied in this sense needs further clarification. We usually refer to the apparent boundary of the sun, which produces the continuous spectrum, as the "photosphere," the sphere of light. In the strictest sense the photosphere is not a sharp boundary but a region. A single thickness of fine gauze may impair but slightly the vision of objects behind it. But a thousand pieces of gauze may be as opaque as a wall. Looking in-

[1] Cf. *Atoms, Stars and Nebulae*, by Goldberg and Aller, Chapter 6.

to the atmosphere of the sun is analogous to looking into a pile of gauze. We see down into gaseous layers where the material becomes substantially opaque to our vision. The portion lying above the zone of complete opacity is what we usually call the solar atmosphere.

The pressure in the photospheric layers, as I have said, is not high—probably of the order of 1/10,000 of the atmospheric pressure at the surface of the earth. Making due allowance for the greater gravitational force of the sun, we estimate that the mass of atmosphere above each square yard of solar photosphere is only about 1 ounce (roughly 1/10 of a kilogram per square meter). The earth, by way of contrast, has about 15 pounds of air over each square inch, i. e., ten tons per square yard. The total mass of the sun's atmosphere is about 200 million million (2×10^{14}) tons. Large as this figure seems, it is nevertheless, about 20 times smaller than the total mass of the air that surrounds the tiny earth.

A very simple experiment confirms our conclusion that the sun's atmosphere is indeed very thin. Dissolve a pinch of salt (sodium chloride) in a glass of water. Heat a wire in a gas flame until all trace of color disappears. Dip the wire into the salt solution and again introduce it into the flame. A brilliant yellow flare, characteristic of the element sodium, results. From the nature of our experiment we know that very little sodium can be in the flame. And yet if we pass white light, say from an incandescent lamp, through the flame, we observe, with a spectroscope, absorption lines far more intense than those of the solar spectrum. The experiment shows that the amount of sodium in the sun's atmosphere is very minute; it further examplifies the great sensitivity of the spectroscopic method and demonstrates the high absorptivity of atoms for light.

From laboratory studies of the spectra of various elements and from theoretical calculations of the ways in which atoms can absorb and radiate light, we attempt to interpret the observed solar spectrum. We find what elements are present and in what amounts. Since the computations and theory are fairly technical matters, I shall not go into tedious details. The intensity of a spectral line is not of itself a clear gauge of the quantity of material present. The atom has a natural tendency to absorb certain colors more readily than others. Also the temperature has a marked effect on the spectrum. There are, for example, thousands of iron lines in the spectrum of the sun. They range in intensity from among the strongest to the weakest in the spectrum. If the temperature of the gas is low most of the atoms resemble the simplest hydrogen atom. The number of colors that such an atom can emit or absorb is very limited and the resultant spectrum will be very simple, consisting of but a few lines. The higher the temperature, however, the more atoms we shall find in other vibrational forms; the spectrum will be correspondingly more complex.

The astronomer puts this principle to practical use. He compares the intensities of the lines that appear only under conditions of high excitation with those of the ordinary lines. The difference in intensity enables him to

gauge accurately the temperature of the source, which is, in this case, the sun's atmosphere. The temperature determined independently by several investigators from studies of the dark-line Fraunhofer spectrum is about 4500° K (7580°F).

This value is about 1500° K lower than that deduced from the quantity and quality of sunlight, as explained in the previous chapter. The figure of 6000°, however, refers to the effective radiating solar surface, i. e., the photosphere, whereas the lower value of 4500° lines are produced in a region known technically as the "reversing layer." It is not surprising to find the atmosphere somewhat cooler than the base, although the 1500° differential was greater than most astronomers expected.

The Solar Atmosphere

One of the goals of solar studies is the determination of the chemical composition of the sun's outer layers. The most intense lines in the visible solar spectrum arise from atoms of ionized calcium, the so-called H and K lines. This observation does not mean than calcium atoms, minus one electron, form the major part of the sun's atmosphere. We have already seen that line intensity alone is not a perfect index. We must correct for temperature, for the intrinsic atomic absorption power, etc.

It turns out that hydrogen, whose lines are much weaker than the calcium ones just mentioned, is actually many thousand times more abundant. The great majority of calcium atoms in the atmosphere are in just the state from which they can absorb the heavy violet lines. However, only one hydrogen atom in a million—we do not know the exact figure—is ready to absorb the visible radiation. To do so, a hydrogen atom must have been previously excited to a high energy state. And at 6000°, not to mention 4500°, the radiation and force of collisional impact are too feeble to pre-excite the atoms. Only in the hotter stars, like Sirius or Vega do the hydrogen lines reach a truly enormous intensity. Helium lines show in stars with still higher temperatures, and ionized helium in the hottest of all. For helium is one of the toughest atoms to dent or to break apart.

Although temperature plays the major role in breaking the atom to pieces, tearing away the outer electrons, pressure also has an important part in the repair or inverse process. An ionized atom must remain so disrupted until it chances to meet and capture some wayfaring electron. And, clearly, its chances of finding the spare part are much greater in matter of high than in matter of low density. For a given temperature, atoms, accordingly, show a higher percentage of ionization under low than high pressure. Conversely, if we know the temperature and if we can further estimate, from the intensities of spectral lines, the numbers of neutral and ionized atoms, we can calculate the pressures.

The value previously quoted, 1/10,000 of an atmosphere, or possibly even a little less, really refers to that of the electron gas. The pressure of the neutral hydrogen gas may be 100 or even 1,000 times higher. The atmospheric density gradually decreases with height above the solar surface as the photosphere fades into the overlying chromosphere. We see

the latter regions most clearly at the time of total solar eclipse, when the moon has completely eclipsed the photosphere. For a brief moment the chromosphere flashes into view, its spectrum consisting of bright lines, appropriate to the tenuous gas. A spectrograph records thousands of crescent-shaped patterns of emissions, each corresponding to a different wave length.

This "flash spectrum," as the phenomenon is ordinarily termed because of its brief duration, bears a marked resemblance to the ordinary Fraunhofer absorption spectrum. These are, however, numerous differences, chiefly in the intensities of the lines of the ionized metals, which appear far stronger in the chromosphere layers. The lower pressure, as previously explained, is conducive to increased ionization.

Low density, however, is not alone the answer to the peculiarities of the flash spectrum. A forecast of the existence of certain difficulties associated with any simple interpretation of the solar atmosphere will be helpful. In the chromospheric spectrum the lines of the hard-to-excite atom, neutral helium, are very intense, although they show up rarely, if at all, in the Fraunhofer dark-line spectrum.

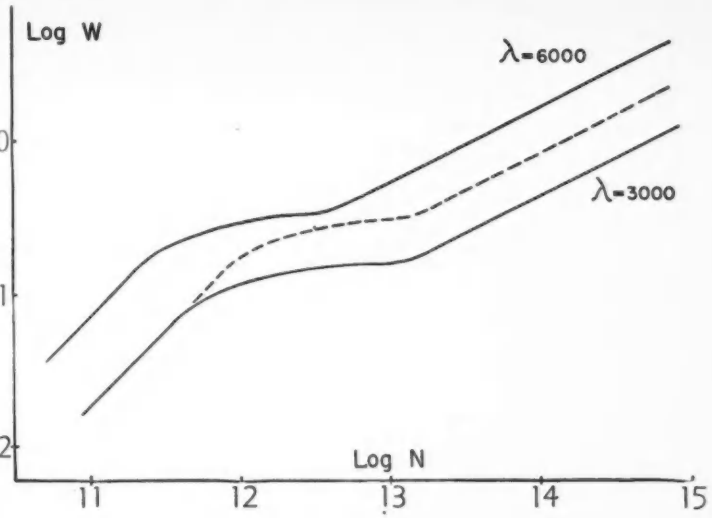
A relatively simple calculation shows that the observed degree of excitation can arise only by the action of either intense utraviolet radiation or fast-moving electrons. The ordinary 6000° solar temperature could not possibly produce the required excitation conditions. A temperature of 20,000° or 25,000° is indicated. I shall not attempt to suggest, for the present, any possible explanation for the discrepancy, for this single observation is just one of many similar difficulties yet to be encountered in our attempts to analyze the complete data and to build therefrom a satisfactory picture of the structure and activity of the sun.

To interpret the intensities of the absorption lines in the solar spectrum, we pose ourselves the following problem. Let us assume that we have only the photosphere and no atmosphere at all. The spectrum would then be purely continuous—unbroken by dark lines. Now let us build up an atmosphere atom by atom. How shall we expect the absorption lines to "grow"?

A given line of the spectrum is not strictly monochromatic, i.e., single colored. Owing partly to an intrinsic breadth and partly to their motions, atoms producing the line will absorb effectively over a small range of color. An atom moving toward the observer will absorb light in the violet edge or "wing" of the line; one moving away from the observer will absorb in the red. The Doppler[2] effect is the cause of the phenomenon. Thus high temperature widens spectral lines, because of the large velocities of the moving atoms.

Iron atoms in the reversing layer, absorbing like the perfect oscillator of a miniature radio set, will produce a barely perceptible absorption line with about 1,000 million (10^9) atoms per square centimeter. Only about 1 per cent of the light will be cut off over a narrow region. Ten thousand million atoms will absorb something like 10 percent over the same region, whereas 100 billion atoms will produce a very

[2] Doppler, an Austrian physicist, was the first person to predict the existence of the shift in color now called by his name.



➤ FIG. 1.—THE CURVE *of Growth Shows the interpretations of solar and stellar spectra.*

black line indeed—almost completely absorbed at the center.

If, now, we increase the number of atoms by an additional factor of ten, the absorption line can grow only a little stronger. The line is "saturated." In other words, it is already so black at the center that most of the further absorption consists of a slight widening.

We measure the absorption in terms of the "equivalent width," the amount of energy that would be subtracted from the spectrum by a completely black, rectangular line of width *W* Angstrom units.[3] We term a plot of *W* against the number of atoms, the "curve of growth." The theoretical curve (Fig. 1) increases sharply for small values of *N*, the number of atoms. Then it flattens off for a piece, finally turning upward again.

The details of this curve are of primary interest only to the professional. The theoretical development is due to many investigators, but the original work was started by the Dutch astronomers, Minnaert and Slob. This curve has proved to be basic in the interpretation of solar and stellar spectra. It is fundamental for quantitative analysis. One measures the *W*. For example, we may find some line in the solar spectrum whose W is one Angstrom unit.[4] Reference to the

[3] Cf. *Atoms, Stars and Nebulae*, by Goldberg and Adler, Chapter 6.

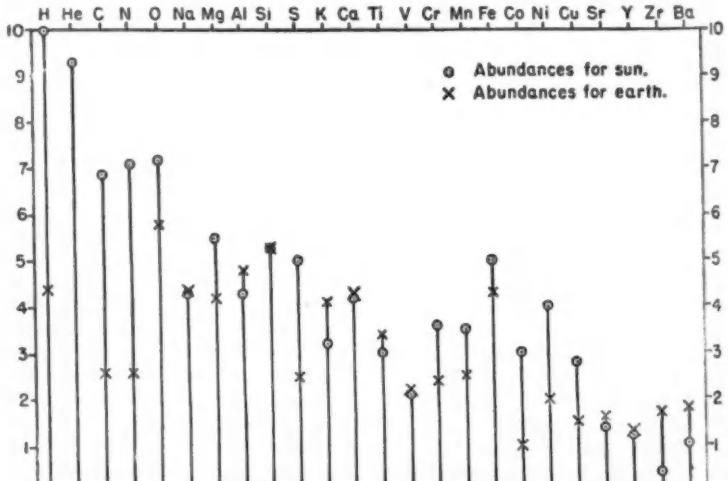
[4] The Angstrom unit, a measure of wavelength, is 1/100,000,000 of a centimeter, or 10^{-8} cm.

curve will show that some 10^{14} atoms per square centimeter are required to produce a line of this intensity.

Of course the problem is not quite as simple as depicted above. Atoms rarely act like the assumed perfect oscillators. One has first to correct the value for the true atomic absorbing power in a given line. And then he must introduce further corrections for temperature, wavelength, etc. The final result is a spectroscopic determination of the chemical composition of the solar atmosphere. The first comprehensive measures of solar abundances were made by Russell of Princeton.

It is of interest to compare the results with the chemical composition of the earth's crust. The conclusions appear in Fig. 2. The proportions of the heavy metallic elements such as calcium, iron, titanium and nickel correspond very well in the two bodies. But the lighter elements seems to be very much more abundant on the sun. The most outstanding discrepancies are for hydrogen and helium. True, the solar occurrence of the latter is quite uncertain. The value is particularly sensitive to small errors in the temperature. If we disregard helium completely, we may say that the sun's atmosphere consists of chemically pure hydrogen. We repeat: the solar gases are chemically pure, but not spectroscopically pure hydrogen.

In this surprising chemical difference between earth and sun we see the start of many questions. The fact that the same predominance of hydrogen as in the sun seems to obtain



➤ FIG. 2.—COMPARATIVE *abundances of elements in the earth and sun*.

throughout the universe lays further stress on the anomaly. Something is wrong with the earth.

The explanation may hold a hint of evolutionary trends. In the primordial scheme, when the earth was young and still hot from the activity that gave it birth, perhaps it had its share of hydrogen. But the lighter elements may have evaporated into space.[5] Our moon has lost its atmosphere completely. So has the planet Mercury. Mars has only a vestige of surrounding gases. The process has been a sort of distillation, in which the less massive planets have lost at least the lighter gases.

In apparent harmony with this view stands the fact that Jupiter, Saturn, Uranus and Neptune appear to have retained most of their original hydrogen. The spectroscope reveals ammonia (NH_3) and marsh gas (CH_4) as abundant constituents of the atmosphere of the giant planets.

To confound our theories, however, Titan, the great satellite of Saturn, also has an ammonia-methane envelope, as Kuiper has recently shown. And Titan is no larger than Mercury, which has lost all of its atmosphere. Of course Mercury is close to the sun, whereas Titan is far away, in the cold depths of space. But if ever the satellite were molten, it should have lost the hydrogen it now appears to possess.

An alternative hypothesis, recently suggested by Kronig, is that the earth's hydrogen has disappeared, not into space, but into the interior. Hot rock, under high pressure, can absorb vast amounts of hydrogen with no perceptible increase of density.

To the peculiar position of the earth in the cosmic temperature scheme, we owe the greatest anomaly of all: the presence of life on the surface of a planet. I mention the subject here because life is indeed a form of solar chemistry. The magical reagent, chlorophyll, snatches energy from a beam of sunlight and locks it up in the growing plant cells. Photochemistry—the chemistry of light—makes life possible.

[5] Cf. *Earth, Moon and Planets*, by F. L. Whipple, Chapter 14.

Phosphorus Reveals Brain Tumors

▶ PROBING the brain with a miniature Geiger-Muller counter will help surgeons locate more accurately the deeply buried tumors that threaten life, Drs. B. Selverstone, A. K. Solomon, and W. H. Sweet of the Massachusetts General Hospital and the Harvard Medical School, have reported to the Journal of the American Medical Association.

Patients suspected of having brain tumors are given injections of radioactive phosphorus from approximately two hours to three days before operation. Tumor tissue concentrates the radioactive phosphorus. When probed by the Geiger counter, the tumor reveals its location by the accelerated ticking of the instrument.

In 14 patients deep brain tumors have been precisely located by this method.

For The Home Lab

Arsenic — Without Lace

by Burton L. Hawk

➤ The chief fame of arsenic arises from its use in murders and committing suicide. It is rapidly being replaced for the latter by sleeping tablets, and even in murders, the cyanides are bringing strong competition. In general, we do not recommend arsenic for suicide as it is slow, agonizing, and usually fatal.

The Metal

Arsenic has been known for centuries As an ore, it was mined by the Romans and Greeks. But it was not isolated as a metal until many years later.

The "arsenic" known to the general public actually is the trioxide of arsenic, As_2O_3. In fact, probably few people realize that arsenic exists as a metal. But, of course, we know better.

Seriously, arsenic *is* a deadly poison and must be handled carefully. Use only small quantities; do not inhale any vapors. Wash your hands and all containers thoroughly immediately after experimenting.

Arsenic is easily reduced from the trioxide by carbon. Mix together equal quantities of arsenic trioxide and powdered wood charcoal. Place a *small* portion of this mixture in a large, narrow, dry test tube. Heat gently at first, gradually increasing. The arsenic will be released as a vapor and condense in the cooler part of the tube, forming a metallic deposit on the walls. If enough heat is applied, you may observe the yellow vapor. Don't inhale! When cool, carefully break the tube and scrape off the metallic crystals with a glass rod.

Arsenic burns in the air forming the trioxide. Sift a small quantity of powdered arsenic into a flame. Note the flash of light and the white cloud of smoke, which consists of fine particles of As_2O_3. Note also the garlic-like odor characteristic of arsenic. Perform this in a well-ventilated room.

Pure arsenic metal is not soluble in hydrochloric or sulfuric acid. Nitric acid, however, oxidizes it to arsenic acid, H_3AsO_4. Arsenious acid, H_3AsO_3, is formed by dissolving the trioxide in water.

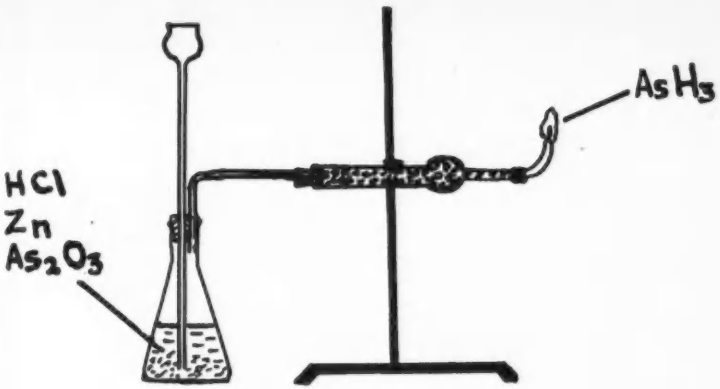
Colorful Compounds

Prepare a solution of arsenious acid by dissolving a small portion of arsenic trioxide in water. It will be necessary to heat, as the oxide is not very soluble in cold water. Add a little ammonium hydroxide, then pour in a solution of copper sulfate. The beautiful yellow-green precipitate, which will dissolve in excess ammonia, is known as *Scheele's Green.*

To arsenious acid solution, add ammonium sulfide. Arsenious sulfide, As_2S_3, is formed in colloidal suspension. If a few drops of hydrochloric acid be added, it will separate as a bright yellow precipitate, known as *orpiment.*

Temperamental Crystals

Here is an unusual experiment, if it works. To a solution of 5 cc. hydrochloric acid in 5 cc. of water, add



➤ *Preparation of Arsine.*

½ gram of arsenic trioxide. Boil the mixture for a few minutes in a small flask. Allow to cool slowly. Shake the flask gently from time to time. Eventually crystals will form, each one accompanied by a flash of light. You had better not plan this experiment for a demonstration show, because sometimes for some unexplainable reason, it just doesn't work.

Reinsch's Test

When a solution of arsenic is boiled with hydrochloric acid and a piece of copper is added, a gray film of arsenic will be deposited on the copper. This serves as a test for arsenic and if only a trace be present it will appear on the copper. To demonstrate, boil a little arsenic trioxide (or any other arsenic compound) with a dilute solution of hydrochloric acid. Immerse in the solution a bright, clean strip of copper. The gray film will betray the arsenic.

Arsine—Marsh's Test

As nitrogen combines with hydrogen to form ammonia, NH_3, so arsenic combines with hydrogen to form *arsine*, AsH_3. Arsine is exceedingly poisonous and there is also some danger of explosion in its preparation. Therefore, we do not recommend this experiment for the inexperienced worker.

Set up a hydrogen generator with a calcium chloride tube attached for drying the gas. Fill the tube with granular calcium chloride, and attach a glass jet to the end of it, as shown in the accompanying diagram.

Generate hydrogen by pouring dilute hydrochloric acid on zinc metal in the flask. Allow the action to continue for a *full five minutes*. Then *cautiously* ignite the gas at the glass jet. As an added precaution wrap a towel loosely around the generator to prevent flying glass in the event of an explosion. Never take chances with hydrogen! Now while the gas is burning, pour a *small* amount of arsenious acid (or any arsenic compound) through the thistle tube into the generator flask. Note the change in color

of the flame and also the garlic-like odor. (Do not breathe it.) Let the flame touch the inside of a porcelain evaporating dish. The presence of arsenic is indicated by the metallic deposit on the cool porcelain. This is an extremely delicate test by which, it is claimed, 0.00001 g. of arsenic can be detected.

Uses

Arsenic seems to be most useful in the role of a killer. As stated before, the oxide is used in murder and suicide. The metal is used to harden lead in manufacturing lead shot. The compounds are used in insecticides for killing the boll weevil and other destructive insects. It is used in rat poisons. It is even used to kill weeds. But, like many other poisons, it can also be used to heal. *Salvarsan*, an organic-arsenic compound, is invaluable in the treatment of the dreaded syphilis.

Oxygen in Steel Making

➤ THE INCREASING use of gaseous oxygen in the British iron and steel industry was reviewed by D. J. O. Brandt of the British Iron and Steel Research Association at the United Nations Scientific Conference on the Conservation and Utilization of Resources.

The use of oxygen instead of air in blast furnaces of various types has made great progress since the closing of the recent war, and is now widely used both in America and Europe. There is still much to be learned relative to its economical application, and the English experience will add to world knowledge.

The open-hearth furnace, the electric furnace and the steelmaking converters have all been shown to benefit considerably under certain conditions. To a lesser extent the blast furnace for the production of pig irons and ferro alloys has also been considered with regard to improving performance with an enriched blast.

The basic causes of the recent upsurge of interest are the world-wide steel shortage and the prospect that within a comparatively short time "medium purity" oxygen will no longer be expensive. Under certain conditions the employment of oxygen may be accompanied by savings both in fuel and certain raw materials.

Oxygen has been applied to the open hearth to accelerate both melting and refining. The electric furnace has also been shown to benefit considerably when oxygen is used as a refining agent. Enrichment of the blast in steelmaking converters has been undertaken at several places, giving increased outputs and improved quality of products.

Enrichment of the air blast in a normal blast furnace has not proved quite so advantageous. This is largely because the blast furnace is thermally a very efficient machine. But the use of small, low shaft furnaces particularly designed for oxygen work may enable low-grade ores to be smelted which were hitherto uneconomical, and may also be applied to the smelting of ferro alloys which normally are produced in the electric furnace.

Mechanism of Poisoning By Lightweight Metal

Beryllium Upsets Carbohydrate Use

▶ A NEW EXPLANATION of the mechanism of beryllium poisoning, which may open the way to development of an effective treatment, was offered at the American Chemical Society's national meeting.

Beryllium, a hard, lightweight metal used in the manufacture of fluorescent lights and in many other industrial applications, has been found to interfere with the body's use of sugar and other foods of the carbohydrate family, according to a report presented by Dr. Kenneth F. DuBois of the University of Chicago Toxicity Laboratory. Collaborating in the report were John Doull and Kenneth W. Cochran.

Entering the body chiefly through the respiratory tract, in the form of dust, beryllium causes serious lung damage that persists and grows progressively more severe, and it can also produce bone cancer, rickets, and a general failure of metabolism, Dr. DuBois has found.

Beryllium's industrial importance has increased greatly in recent years because of the highly valuable properties of its alloys, particularly the copper-beryllium alloys. The chances for exposure to beryllium dusts are fairly numerous in industry and may be encountered during virtually all stages of beryllium production.

Since the metal is now recognized as one of the most toxic, care is being taken to protect workers from exposure, and health organizations have warned the public of the possible health hazard arising from broken fluorescent light bulbs.

Despite intensive investigation of beryllium, the manner in which it produced its toxic effects had not been determined previously, although it was known to be retained in the body for a long time. In many instances, poisoning symptoms have not appeared until long after exposure to the dangerous dust.

When Dr. DuBois and his associates launched their inquiry into the metal's mechanism of action, they suspected that beryllium might interfere with chemical reactions essential for normal metabolism, that is, the processes involved in the continual building up and destruction of the body's basic protoplasm.

Rapidly advancing knowledge of the chemistry of living cells has indicated that cellular function is regulated by an intricate system of chemical reactions, he explained. The introduction of a foreign chemical into the body may interrupt the normal sequence of chemical events, throwing the energy-yielding reactions out of balance and resulting in a loss of the ability of tissues to perform their usual functions. In this connection a poison may be defined as a substance which, by chemical interaction with cell constituents, either hastens or retards the chemical reactions in cells, thus disrupting the normal activity of the cell.

On the assumption that beryllium acts in this manner, Dr. DuBois and his associates directed their attention toward ascertaining which chemical reactions might be interrupted by the metal. This involved testing the effect of the metal on a number of reactions known to be important in cellular metabolism.

In their studies it was found that beryllium interferes with carbohydrate metabolism. A rapid rise in blood sugar occurred after injection of beryllium, and a depletion of the carbohydrate reserve (glycogen) occurred. In addition, there was a striking alteration in some of the phosphorus compounds of tissues involved in carbohydrate metabolism. Phosphocreatine, which is an important compound for the energy-yielding reactions of tissues, was depleted and there was a marked shift in the ratio of organic to inorganic phosphorus resulting from a breakdown of organic phosphorus compounds.

In an investigation of the specific manner in which beryllium produces these effects, it was found to compete with calcium and magnesium, both of which are necessary for the breakdown of carbohydrate. Beryllium appears to combine with the same compounds in the cell as do calcium and magnesium, but it cannot perform the biological functions of these metals and, therefore, blocks the sequence of normal chemical events in the cell.

These experiments demonstrated the ability of beryllium to interfere with carbohydrate metabolism which normally provides the immediate energy for cellular function. The results emphasize the value of the application of chemistry to medical problems.

After the mechanism of action of a toxic substance is understood, attempts to treat the condition can be undertaken in a scientific manner. Fundamental research on the chemistry of beryllium poisoning may lead to the development of an effective means of overcoming or of preventing it.

TCA New Chemical Weed-Killer

➤ TCA has joined 2,4-D in man's war against weeds. This new killing compound, tri-chloro-acetic acid, is recommended for use against certain weed grasses, such as quack-grass and Johnson grass, as well as against prickly-pear cactus.

Its value for this purpose was discovered by Du Pont research biologists at their pest control research laboratories. Subsequently, tests were made at the Kansas State Agricultural Experiment Station by J. W. Zahnley, station agronomist, and G. L. McCall, a Du Pont Company biologist.

TCA is recommended especially for use on grass and cactus patches that have resisted other means of eradication. It creates a kind of temporary desert, where nothing at all will grow for from one to three months. For this reason it is distinctly not recommended for use on lawns or golf courses. The temporary soil sterility which it creates, however, passes off after a longer or shorter time, depending on the rainfall.

Non-Corrosive Metal Will Fill Useful Role

Titanium Has Dramatic Possibilities

▶ A BRIGHT and useful future in industry, the home, and military service for the aristocratic metal titanium is predicted by Dr. O. C. Ralston, chief metallurgist, and Dr. F. J. Cservenyak of the United States Bureau of Mines, Washington, D. C., who list more than a hundred potential applications.

Although the metal is so difficult to refine that it does not promise to compete in price with aluminum, copper, and steel, titanium's unusual strength, lightness, and defiance of corrosion are invitations to enterprising scientists and engineers, Dr. Ralston and Dr. Cservenyak declared in a report to the recent national meeting of the American Chemical Society.

Since titanium is believed to be the fourth most plentiful metallic element in the earth's crust, outranked only by aluminum, iron and magnesium, and since rich ores have already been located by the titanium dioxide industry, there will be no lack of natural resources to hamper the growth of a titanium metal industry.

In the form of the oxide, which is an outstanding white pigment, and as an impure metal, which has been used in alloying steel and aluminum, titanium is being extensively employed. Development of the pure, strong, and ductile metal, however, is just now getting into full stride.

One of titanium's most dramatic potential uses is in aircraft, where it should partially replace high-strength light alloys of magnesium and aluminum, according to the report, which explains that while aluminum and magnesium begin to weaken as the temperature goes up above 300 degrees Fahrenheit, titanium retains its strength. Elevated temperatures are becoming increasingly common in modern high-speed planes.

The metal's remarkable resistance to corrosion has aroused the enthusiasm of Navy men, who are continually plagued by the effect of sea water and salt spray on most metals. Corrosion tests on titanium in sea water have shown scarcely any effect on the metal and indicated that titanium is more resistant to salines than any common engineering material.

The life span of naval equipment subject to corrosion could be greatly prolonged by the use of titanium, and this metal would thus compete economically with materials now produced at lower cost.

Among the specific shipboard uses for titanium, the report listed the following: piping systems to handle salt water, condenser tubes, plumbing fixtures, bearings, radio aerials, and small propellers.

Army engineers, the report continued, are interested in titanium for such equipment as truck bodies, girders and other members of portable bridges. Air-borne equipment used by future armies undoubtedly will utilize light-weight, strong titanium advantageously.

Because titanium resists highly corrosive foods such as pineapple juice, vinegar, lard, tea, coffee, grapefruit juice, and lactic acid, the metal could be used for food handling and processing equipment in restaurants and packing plants. Its inertness to strong acids and alkalis makes it suitable for chemical factories.

In the home, titanium hairsprings may be used in control equipment such as time devices for water softeners which are installed in basements and now give trouble because they rust from dampness.

The 2,000,000 orthopedic patients in the United States who wear full braces could replace their heavy steel appliances with lighter ones made of titanium.

Sporting equipment, such as golf club shafts, tennis racquets, and fishing rods, would be light and rustproof if made of titanium.

Concrete to Bury Atomic Wastes

➤ A CEMENT mixer may be a part of the atomic-age laboratory equipment of the scientist who uses the radioactive byproducts of the atomic bomb.

The cement mixer would do the job of a garbage grinder or the kitchen sink. One method of getting rid of radioactive waste materials, is to make concrete.

Radioactive waste materials are put in the liquid used in making the concrete. The hardened concrete is then stored away, dumped in the ocean or buried on land. The method of disposing of the radioactive concrete which should be used depends on the material.

Laboratories can dump the radioactive materials down the drain, but they are advised to follow technical rules in doing it.

Recommended ways of getting rid of radioactive wastes are listed in an Atomic Energy Commission report for scientists using these forms of chemical elements, which are now available to them on a relatively large scale.

If you want to put any of these radioactive isotopes down the sink, you must make sure that the main sewer is getting plenty of water to dilute the chemical. And the plumbing should be checked regularly for radioactivity, especially before any repairs are made.

The quantity of radioactive material which can be safely discharged into a sewer is stated in terms of radioactivity rather than quantities of the element. The unit used is the curie, named for the famous French scientists who discovered radium. It is the activity of 37,000,000,000 atomic disintegrations per second.

In letting radioactive iodine go down the sink, only one-half of a millionth of a curie should be discharged per liter (1.1 quarts) of water. And no scientific institution should let more than 200 thousandths of a curie of radioactive material get into a main sewer in a week.

The report on interim recommendations for disposal of the isotopes lists only iodine with an atomic weight of 131, phosphorus 32 and carbon 14. These three elements account for 90% of the activity of isotopes shipped to scientists thus far.

Third Article of a Series on
What We Know About the Atom

Electricity and the Atom

➤ Evidence that comes to our senses directly from the atom is the foundation of present day atomic theory. Although the concept of miniature solar systems, whose whirling electronic planets may best be described only in terms of advanced mathematics, seems a very abstract picture, atoms are real. Ninety-two kinds of them make up the entire universe. Four more have been added by man's genius within the present decade, and they turn out to be just four more elements whose properties are specific but not unexpected.

Among the properties of the elements which prove the atomic character of their ultimate structure are: their habit of combining in definite quantities by weight, and their ability to form series of compounds of the same elements in which the weights are in simple ratios. The fact that the atomic weights of the elements are almost as clearly multiples of the weight of hydrogen led very early to the hypothesis that they are all built up of units of hydrogen or something similar. The slight fraction by which the weights of the other elements miss being exact multiples of that of hydrogen still furnishes one of the most fascinating puzzles in the realm of atomic physics.

Many properties of the elements shed additional light on the inaccessible region governed by atomic laws. In the previous articles of this series, information gained from the spectra of the elements has been given in the words of the scientists who made the discoveries. Bunsen and Kirchhoff described their spectroscope. Fraunhofer and Ångström told of the dark and bright lines which characterize the spectra of the elements. Spectra have much more information to give about the structure of matter, and this will come later in the series.

Another of the ways by which we reach the atom is through study of the electrical forces which originate there. Exploitation of electricity as a source of power has made us familiar with this mysterious form of energy, so that the casual observer might not recognize it as one of the master keys to the riddle of the universe. Even more surprising than the atomic structure of matter is the fact that energy, too, is made up of discrete bundles, of which you have all or none.

The steps by which scientists learned the fundamental facts about electricity are summed up in the following quotation from a lecture by Sir Ernest Rutherford, who saw most of it happen, originated much of the experimental work that brought it about, and trained many of the scientific leaders carrying on the researches today.

The Atom's Electric Charge

ELECTRICITY AND MATTER, *by Sir Ernest Rutherford. Cawthron Lectures, Vol. III. Nelson, New Zealand, 1928.*

➤ FROM THE VERY beginning the question of the relation between electricity and matter was prominent in the scientific mind, and Franklin (1706-90), who was greatly interested in this matter, propounded as a cause of electrification the existence in all bodies of a subtle and imponderable fluid. When the object was electrified positively, it contained some excess of this fluid, and when it was charged negatively there was a deficiency of the fluid. A little later the two-fluid theory of Symmer (d. 1763) was put forward; this theory regarded electricity as two imponderable fluids; one positive and one negative. For the interpretation of the then known facts the two theories were of equal value and for a long time no direct test could be made between them.

As we look back to the early days of electrical experiments, we see that fundamental facts were discovered, which, properly interpreted, might or should have thrown a great deal of light on the relation between electricity and matter. The experiments of Galvani (1737-98) and Volta (1745-1827) brought out the remarkable fact that by placing certain metals in acid or salt solutions electrical energy was developed, obviously showing a relation between electricity and chemical change.

But the most fundamental experiments of all were due to the genius of Faraday, who about the year 1830 in his Fifth Series of Electrical Researches, investigated the laws governing the passage of electricty through conducting solutions, a phenomenon known as electrolysis. Faraday found that this apparently complex phenomenon was governed by very simple quantitative laws, and showed conclusively that there was a close connection between the quantity of electricity passed through a solution and the weights of the elements which were liberated at the electrodes. He found that for a given quantity of electricity the weight of an element deposited was not exactly proportional to the atomic weight of the element but was proportional to the atomic weight divided by a whole number (now known as the valency), either one or two or three or four, etc. Faraday himself had a fairly clear conception that this was a result of fundamental importance, for it pointed to the fact that electricity is discontinuous, and that there is a definite indivisible unit of electricity as there are definite unit portions of matter (which we call atoms). He showed further that the weight of any element liberated by the passage of a given quantity of electricity is directly proportional both to the quantity of electricity passed and to the atomic weight of the element, but inversely proportional to the valency or number of electric charges carried by the atom. The results of Faraday's experiments, when properly interpreted, showed that electricity was atomic in nature and that not improbably the charge on the hydrogen atom in the electrolysis of water was the unit charge of electricity.

But the time was too early for the full meaning of Faraday's experiments to be understood, and it was nearly half a century before the question came again into prominence. An idea was then put forward by Johnstone Stoney of Dublin, who stated that from Faraday's laws it was evident that electricity was atomic in nature, and he proposed that the charge carried by the hydrogen atom in electrolysis should be called the *electron*. Today the term electron does not necessarily apply to the unit charge itself, but to the carrier of this unit charge.

The more definite proof of the unit or atomic nature of electricity ultimately came from the discovery, or rather the proof, of the independent existence of what we now call the electron through the study of the so-called cathode ray. Many of you may have seen experiments showing the remarkable phenomena observed when an electric discharge is passed through a gas at a very low pressure. Under certain conditions rays are shot out from the cathode or negative electrode like a luminous stream, and this stream has been shown by Sir J. J. Thomson and other physicists to consist of a very large number of particles of electrons, each particle carrying a negative electrical charge and travelling with a speed exceeding in some cases 100,000 miles per second. The mass of any one of these particles is exceedingly minute compared even with that of the hydrogen atom, the lightest atom known to us.

Before discussing the question as to the place which these electrons take in our theory of the structure of matter, I must endeavour to explain how we have been able to determine the magnitude of the unit charge. Lord Kelvin once said very wisely that in physical science we know nothing definitely about anything until we can measure it. A large amount of work has been done and a great deal of energy spent in proving in a simple way that electricity is atomic in nature, and in measuring the magnitude of the unit charge.

By the statement that electricity is atomic in nature, we mean that an actual quantity of electricity may contain one unit or two or three or one hundred units, but there must be a whole number of units and there cannot be any fractional parts of a unit. We shall see that the whole simplicity of the structure of matter depends on this *atomic* nature of electricity.

If we accept Faraday's theory of electrolysis we can deduce important consequences from it. Faraday discovered that 9573 electromagnetic units of electricity passing through acidulated water always liberated 1 gram of hydrogen.

Thus if N is the number of hydrogen atoms in a gram and M the mass of each atom and e the charge carried by it (equal to the electronic charge) we have, $Ne = 9573$, $NM = 1$. By division we obtain the ratio of charge to mass or $\frac{e}{M} = 9573$ for hydrogen.

If, therefore, we can determine the elementary charge we can determine the mass of the atom and the number of atoms in a gram.

We will pass over a number of methods that were devised to measure this charge, and proceed to the latest method of precision, a method devised

and worked up by Millikan and his students at Chicago, based on the earlier work of C. T. R. Wilson, H. A. Wilson, J. J. Thomson and J. S. Townsend.

A little droplet of oil or mercury, just visible in a highpowered microscope, is electrified by friction by projecting it through a small orifice and has thus an unknown charge upon it. The droplet is allowed to enter between two plates across which an electric field of known magnitude can be generated. It is thus possible to adjust the electric force so that the droplet is supported in space like Mahomet's coffin, and as long as its charge remains constant the particle will remain suspended. In this experiment the weight of the droplet acting downwards is balanced by the electric force upon it, this electrical force being proportional to the magnitude of its electric charge. The charge on the droplet is now changed, and for that purpose we make use of the X-rays to "ionize the gas." That is, when we pass the rays in a narrow beam between the plates creating the field, the air molecules are acted upon — by the rays — and a number of positively and negatively electrified particles called "ions" are produced. These ions consist of an assemblage of a few molecules clustered round a positive or a negative charge. The differently charged ions can be separated by the electric field, the positive being pulled towards the negatively charged plate and the negative ions in the opposite direction. Very soon one or more of the ions will come in contact with the charged droplet, thus decreasing its charge without appreciably altering its weight, as the ion is of negligible mass. The drop will be no longer balanced, since the upward electric pull will be reduced while the gravitational pull downwards will be unaltered. To restore the balance the electric field must be changed. From the alterations of electric force needed to balance the drop with successive alterations of electrical charge it is found that these added charges must be either one unit or exact multiples of a unit, 1, 2, 3, or 4. Fractional charges are never obtained.

Based on this method Millikan has been able to determine the magnitude of the unit of charge with great precision. Its value is 4.774×10^{-10} electrostatic units or 1.591×10^{-20} electromagnetic units of quantity. Combining this value of e with the ratio of e/M from the data of electrolysis we have been able to determine with precision the actual weights of the individual atoms of the elements, and with an error probably not exceeding one in a thousand — a very remarkable result. The numbers obtained from this experiment, $N = 6.06 \times 10^{23}$, $M = 1.662 \times 10^{24}$ agree with those arrived at by a number of other methods, so we feel confident that the values are correct.

I have so far proceeded on the assumption that matter consists of atoms, and we will now pause for a moment to consider in a very simple way what are the sizes and masses of the atoms.

From the earliest days many philosophers considered matter to be discontinuous or atomic in structure, and a definite theory was enunciated by Dalton in 1806 in order to explain the combinations of gases in multiple proportions. From that time the

atomic theory has been of fundamental value to chemists in explaining and predicting the facts of chemical science. For the explanation of these facts it was not necessary to have an actual knowledge of the size or real weight of the atom. All that was required was to know the relative weights (termed atomic weights) of the atoms of the different elements and to suppose that any ordinarily perceptible quantity of matter must contain a very large number of atoms. But many attempts were made, especially by Lord Kelvin, to estimate the size of atoms, and we may say that we now know approximately their diameter. Two hundred million of them side by side in a straight line would cover about an inch. The atoms of one element differ from the atoms of another in size, but the differences are not very great.

The minute sizes of these atoms may be illustrated in another way. Let us consider a cubic centimetre of air, a volume less than that of the end joint of my little finger. The number of atoms in this small volume is almost incredibly large. If everybody in the world counted these atoms for 24 hours daily, and if each person counted a hundred a minute, it would take about a thousand years to count the atoms in that cubic centrimetre of air. We can therefore appreciate the difficulty of the problem set before the physicist and the chemist when they try to explore the structure of one of these incredibly minute atoms.

I will now illustrate in a number of ways that although the atom is so small and the number of atoms so great, yet, in special circumstances, we can detect a single atom of matter. In order that its presence may be detected an atom must be differentiated in some way from its neighbours. We cannot expect to see the atom, but if it is caused to move faster than its neighbours and also given an electric charge, its individual presence can be detected. The first time this experiment was carried out was in 1907 by Dr. Geiger and myself in Manchester. It was accomplished by taking advantage of certain properties of the element radium or of some other radioactive element which ejects alpha-particles or positively electrified atoms of helium which have lost two negative electrons. We were able to work out a method by which it was possible to magnify the effect of a single alpha-particle so that an effect was produced easily detectable by a certain electrical instrument. This consists of a small detecting chamber, a brass vessel about the size of a thimble with a sharpened needle-point in it. At one end of the vessel there is a small opening, and into that opening the alpha-particles are alowed to enter, and each one as it enters causes ions to be produced. If the voltage between the case and the needle-point is adjusted the effects are magnified enormously, and a large current passes through the contained air. The entrance of a single alpha-particle can be detected by connecting the needle to a string-electrometer which records a little "jump" on a photographic film at the entrance of each particle. If we examine a large number of the records of these instruments we see that the alpha-particles are emitted from the radium and enter the chamber according to the ordinary laws of chance and that

the variations are in agreement with the laws of probability.

Another apparatus designed by C. T. R. Wilson, of Cambridge, has thrown a flood of light on the question of what happens to the alpha-particles as they fly through the gas. It is merely a plunger in a small cylinder containing air or some other gas saturated with water vapour. If the plunger is pulled out slightly the gas is cooled by expansion and becomes supersaturated. Wilson made the fundamental discovery that charged ions produced by alpha-particles, or other sources of ionisation, become nuclei for the condensation of water vapour. In this way each ion produces a visible drop of water in the supersaturated air, and if the number of droplets following one another is sufficiently large, the track of the particle can be followed. A very minute trace of radium is employed to produce the ionisation and the separate particles are clearly shown. The drops may be so numerous that they form an almost continuous line. The swift alpha-particle travels nearly in a straight line, and it plunges through the molecules in its path. Professor Wilson has recently shown by photographs the difference between the track of an alpha-particle and the track of a swift electron. The paths of the relatively slow moving alpha-particles are shown by coarse lines, whereas the electrons moving at the rate of approximately 100,000 miles a second are shown by faint lines only. The numbers of ions produced by the electron are so few that they can be counted. Thus the track of a particle and the points where single ions are produced may be distinctly observed. We know that each of these particles carries a single charge, so that in fact we are seeing the effect of the unit charge on the particle.

The enlarged photographs of the tracks of the electrons are very beautiful and they show what have been the main events in the history of each electron, notwithstanding the incredibly short time occupied by the electron in describing its path — a time less even than one-thousandth of a millionth of a second. The photograph will show that at one point an electron encountered an atom and liberated another electron which came out at a fairly high speed and ionised other molecules encountered in its path. At another point it may be found that the encounter with the atom has turned the path of the electron through a right angle. When these effects were first deduced from other experiments and from theory in 1911, I could never have believed that within a few years a powerful method would be developed enabling us to see every detail of the history of the flying particles. These photographs bring home to us very vividly the individual existence of the electron and the alpha-particle, and the main facts of their very short but very lively careers.

I must now pass on to the question of the bearing of what I have already said on the main subject of my lecture. We have seen that the negative electron carries a unit charge and that we can isolate it and detect it. But now we come to the question of the relationship between these unit-charged electrons and the atom itself. It was shown soon after the discovery of the electron that the electron itself

must be one of the constituents of the atoms of every element, and this was deduced not only from the fact that the electron can be removed from any atom, but from the nature of the light emitted from the atom in the process. It was found that the vibrator which gives rise to the undulations which we call light is the electron vibrating under the influence of the forces holding it in its place in the atom.

We were sure that every atom of matter contained negative electrons, but the problem has been, and still is, how many of these negative electrons there are in any particular atom and how they are held together in the atomic system.

An atom is electrically *neutral*. Ordinarily it has no charge, and therefore the amount of positive electricity in it must balance the amount of negative electricity, and the main difficulty of the question of atomic structure has been due to our uncertainty as to the nature of positive electricity. We believe that the negative electron is in a sense a disembodied atom of electricity, or nothing more than electricity itself in a small space, moving about without any independent matter, as we understand the term, attached to it. The electron has small mass, but we know that the electrons account for only a small proportion of the mass or inertia of the atom and the electrons in an atom are responsible for only a small fraction of the total mass. The question arises: Is there a positive counterpart of the negative electron, i.e., a positive electron of small mass?

(EDITOR'S NOTE: *At the time Rutherford wrote the article from which this quotation is taken, the discovery of the positron, the positive electrical unit whose mass is comparable to that of the electron, was still in the future. The positive charge on the nucleus of the atom was believed to be the only manifestation of positive electricity. Likewise in the future was the discovery of the neutron, whose place in the architecture of the atom was at that time thought to be filled by a balanced pair — proton + electron. The facts known to Rutherford have not been superceded. Our ideas of the structure of the nucleus have become more detailed as more data on the subject has accumulated. How the atom is built will be the subject of the next chapter in this series on what we know about the atom.*)

Guide to Uranium Prospecting

A POCKET-SIZE booklet issued jointly by the U. S. Atomic Energy Commission and the U. S. Geological Survey is full of information relative to uranium ores.

The booklet classifies the uranium ores, tells what they look like, where they are apt to be found, and how they can be tested. It discusses fluorescence and radioactivity and the use of the Geiger counter, the standard instrument for radioactivity detection. It even gives the manufacturers and distributors of portable Geiger counters suitable for prospecting.

"Prospecting for Uranium" can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 30 cents.

Three Ways to Prevent Microbiological Losses

Army Fights Textile Destroyers

➤ THE ARMY Quartermaster Corps, with a host of civilian allies, has won a major victory over microbiological foes that cost the nation millions of dollars a year through destruction of cotton clothing, tents, and other textile products.

Development of a chemical armor that guards cotton fabrics against fire, light, and water as well as invading microorganisms was reported to the American Chemical Society's national meeting by Dr. Ralph G. H. Siu, research director of the General Laboratories, Quartermaster Research and Development, Philadelphia. Dr. Siu addressed a symposium on the "Degradation of Cellulose" sponsored jointly by the Society's Division of Cellulose Chemistry and the National Research Council.

The new cotton treatment, in which the surface molecules of the cellulose fiber are chemically changed, is of enormous significance to the civilian as well as to the soldier, it was pointed out, for bacteria and fungi wreak wide havoc against cotton, rayon, wood and other cellulose products in many fields. Heavy losses are caused, for example, by the dry rot of buildings and timber, the decay of wharf pilings and fishing nets in the sea, the deterioration of paper pulp in mills, and the mildewing of shower curtains, upholstery, wallpaper and awnings in the home.

A far-flung battle against these microscopic enemies was waged by the Quartermaster Corps, in collaboration with the National Defense Research Committee, during World War II, Dr. Sui recalled, and after the war the fight was continued by the Quartermaster Laboratories with the help of dozens of industrial laboratories, universities, various government agencies such as the Department of Agriculture, and the British Commonwealth Scientific Office.

In cooperation with the Air Force, a tropical science mission was conducted to observe the effects of deterioration in the tropical and subtropical belt, which resulted in the world's largest collection of microorganisms that damage material. This collection is now maintained at the Quartermaster Research and Development Laboratories.

A striking illustration of the economics involved in the microbiological degradation of cotton textiles was the rotting of cotton textiles during the Allied tropical campaigns of World War II, when more than 35 million yards of canvas per month were purchased for tentage alone, Dr. Siu noted. In tropical areas, cotton textiles were rendered useless from attack by fungi and bacteria after a month of storage or exposure. In many cases the material was decomposed in the hold of the ship even before arriving at its destination.

These alarming losses gave a tremendous stimulus to research in Canada, Great Britain and this country

during the past six or seven years toward the prevention of microbiological attack, he explained.

Preliminary studies of the manner in which microorganisms attack cotton fibers revealed the following general picture, according to Dr. Siu:

The microorganism, carried by wind and dust onto the cloth, germinates when conditions become sufficiently moist and warm. In germinating, it secretes enzymes which attack the cotton. Cellulose, which is the building material of cotton, is rapidly converted into sugars. These sugars are then used as foodstuff by the microorganism. In this process, the breakdown begins at the point on the cotton fiber in immediate contact with the microorganism. As more and more cellulose is converted into foodstuff, the microorganism produces new offspring, which germinate and begin their own cycle of development. Gradually the entire cotton fibers are dissolved, bringing about a complete disintegration of the fabric.

There are three points at which the cycle can be broken, according to Dr. Siu. First of all, the invading microorganism can be killed or its growth can be arrested by impregnating the fabrics with inhibitory compounds called fungicides. More than 1,000 such compounds have been tested, and many satisfactory fungicides have been developed. This is the method most generally used. Formulations containing a substance known as copper-8-quinolinolate have been particularly effective, he said. As little as one-tenth of 1 per cent of the more potent fungicides will enable a fabric to withstand cellulose-destroying organisms for several months, even under conditions where an untreated fabric would last only a week or two.

Fungicides as a class have several disadvantages, however. Some are readily leached out by rain, while others accelerate the destructive effect of sunlight on fabric. Still other fungicides are toxic to human beings, making them useless on clothing, straps, and other articles that touch the skin. Frequently, the presence of fungicides interferes with other treatments used to give flame and water resistance, and in many instances the cost is prohibitive.

These disadvantages spurred the search for other methods, Dr. Siu said, and the placing of a thin inert barrier between the organism and the fiber was tried. Treatment with certain resins, such as urea formaldehyde, was found to be effective, although for the most part they added 5 to 15 per cent to the fabric's weight and gave it a "boardy" feel. Such treatments, however, are fairly permanent and relatively non-toxic, so that after further study they may have considerable value.

The most ingenious of the three general methods, however, is based on the way enzymes secreted by the organisms attack the cellulose molecules of the cotton fibers.

Apparently the enzymes will not attack these molecules if they are chemically altered in any of a great variety of ways. If the molecules of thin surface layers of the fiber are modified in a chemical fashion, one will effectively have, as in the case of resin impregnation, a thin inert barrier protecting the rest of the cotton fiber. The great advantage of this so-called topochemical method of pre-

vention lies in the fact that the cellulose molecule can be so changed chemically that the resulting fiber will not only be resistant to mildew, but can by one and the same treatment be made resistant to light, water, or fire. The fact that the cellulose molecule is chemically changed makes the cotton resistant to mildew; the nature of the change gives the other desired properties. By proper selection of the chemical reagent, one is able to "tailor-make" cotton fabrics with various combinations of properties.

At present, many laboratory topochemical treatments have been made in which mildew-resistance and other properties have been imparted to the cloth. One or two have seen limited commercial production, such as the acetylation and the urea-phosphate treatments. As far as theoretical promise is concerned, this topochemical approach appears most promising, and much work is being carried out attempting to translate successful laboratory findings to commercial processes.

King Cotton Losing to Synthetics

➤ COTTON is still America's number one textile fiber, used more than all others combined, but other American natural fibers and man-made fibers are forging ahead and gradually decreasing the cotton lead.

Cotton supplied 57.4% of the nation's needs in 1948, compared to 58.4% in 1947 and 60.6% in a five-year period preceding the war, according to figures of the U. S. Department of Agriculture. Rayon held second place, 14.9% of the total, with wool, jute, sisal and Manila hemp, flax, and synthetic fibers other than rayon supplying most of the rest. Wool is widely used in many textiles, but this animal fiber makes up only 10% of the total fiber consumed in the United States.

Rayon consumption in 1948 reached an all-time high of 1,017,000,000 pounds. Flax is a minor fiber in American producton, the total used being only 0.2% of the total fiber consumption. Synthetic fibers other than rayon are beating even the rayon increases; 70,700,000 pounds were consumed in 1948. These include nylon, glass fiber, casein fiber, zein fiber and synthetic resin fibers.

Until about 1935, rayon was the only synthetic fiber produced commercially in the United States. It was made from cellulose. Glass fiber is the oldest non-cellulosic synthetic fiber. Its output, commercially, began about 1936. About two years later production of Vinyon, made of Vinylite synthetic resin, was started. Commercial production of nylon, most important of the synthetic fibers, began in 1939, following a short period of pilot-plant operation.

Considerable research is under way to develop additional synthetic fibers, particularly from vegetable proteins and synthetic resins. Included is work on peanut and soybean protein fibers, already developed but not yet produced commercially in America. Process for the production of fibers from cottonseed protein and from the metal salts of modified cellulose are under study at the department's Southern Regional Research Laboratory.

New Developments Among Plastics Yield Specialized Materials

Better Plastics for Tougher Jobs

A PLASTIC which cannot be dissolved by any known solvent at ordinary temperatures, and which is unaffected by such potent chemicals as sulfuric acid, hydrochloric acid, nitric acid, and caustic soda, was described to the American Chemical Society by a group of chemists from Oak Ridge, Tenn.

The plastic, known as Fluorothene, which enables scientists to conduct experiments hitherto impossible, is being manufactured for the United State Atomic Energy Commission by the Carbide and Carbon Chemicals Corporation at Oak Ridge, and is also being produced commercially under a different name by another company. The material is made of chlorotrifluoroethylene. It is one of the fluorine plastics made possible by World War II research on the atom bomb project.

The remarkable properties of the plastic, and its use in making filters which are chemically resistant to almost all reagents, were discussed in papers by S. E. Frey, J. D. Gibson, R. H. Lafferty, Jr., W. H. Reysen, D. S. Napolitan, and W. T. Daniel.

Noting that some solvents may swell the material, but that extended immersion tests with 125 different chemicals at 77 degrees and 158 degrees Fahrenheit failed to dissolve it, the chemists said "this quality of inertness, coupled with its excellent mechanical strength and comparative ease of fabrication has enabled research workers to use it in certain operations which previously had been impossible to perform."

Tubing, fittings, flasks, test tubes, beakers and many other special pieces of equipment have been made of the new plastic, but until recently the scope of experiments that could be conducted with its aid has been limited by lack of a filter of comparable chemical resistance. Now, however, this problem has been solved by a method in which finely-divided Fluorothene is flame-sprayed on a suitable base in such a manner that a porous, multi-layer coating is obtained. Porous filter disks as large as 16 inches in diameter and a half inch thick have been prepared from this material, the reports said.

In general, these disks are not attacked by acids and most organic solvents, and in addition they are not wet by water. Some have been fabricated which were almost shatterproof, and all withstood a considerable amount of flexing.

Because of the present high cost of Fluorothene and the large amount of labor involved in preparing filter disks, it is not anticipated that this material will replace any of the filtration mediums in present use, but in those cases where the filtration of highly corrosive or radioactive materials is still a serious problem and cost is a negligible factor, Fluorothene filters appear to be ideal.

Why Substances Jell

➤ NEW INFORMATION about the mystery of why certain chemical substances "jell" may come from study of synthetic chemicals in Kodak Research Laboratories, Rochester, N. Y., according to reports of Kodak scientists at the meeting of the American Chemical Society.

Two types of experimental synthetic polymers were described. One type has to do with gelatin, another with cellulose. Both gelatin and cellulose are important in photography. Scientists have worked for years to learn more about their make-up and the way they behave.

One report, by Louis M. Minsk and Dr. William O. Kenyon, described the preparation of a unique synthetic material known as "imidized polyacrylamide." This substance, they found, has certain of the physical properties of gelatin. It is one of the few synthetic substances which "jell out" of solution in water.

Gelatin is widely used in photographic film. It is the material which, when combined with silver salts, forms the light sensitive photo emulsion. Gelatin, however, is a complex substance. Its structure has not yet been completely explained.

This is where the value of polyacrylamide comes in, the scientists point out. The synthetic material is far less complex in structure than the natural gelatin. It has only three structural components. The scientists, knowing the make-up of the synthetic material, can make variations in these components to aid them in their study. They also can control the molecular weight of the polymer.

The researchers believe that the synthetic material "jells" like gelatin because of the attraction between the long molecules which make up this material, and because these molecules are so constructed that the amount of water forming a part of them can be controlled.

The study indicates that, physically, a gel is the intermediate phase between a precipitate and a solution, much as a jelly is midway between a solid and a liquid.

Research on another type of synthetic materials, ester lactones, was also reported by Mr. Minsk, Dr. Kenyon and G. P. Waugh at the meeting. These may be cast from organic solvents into clear transparent sheets which have high strength, low stretch, and moderately high rigidity.

These ester lactones are of scientific interest because they contribute indirectly to the study of cellulose. They have a chemical structure which, in one particular respect, appears to be akin to that of cellulose. The physical properties of their sheets are somewhat like those of cellulose esters.

Both of these studies are a part of Kodak research into the structures which contribute to the properties of natural polymers through a study of purely synthetic polymers of known and controllable composition.

Cheaper Raw Material

➤ THE COST of transparent plastics can be lowered considerably as a result of a process to manufacture them from blackstrap molasses.

The plastics involved are of the type popularly known under their trade names of 'Lucite' and "Plexiglass." They are used on a wide variety of

articles, ranging from brush handles to airplane noses, where their transparency makes them advantageous. They have often been used in place of glass in modern furniture, on trains and for towel racks. The new process may further the use of this glass substitute.

The process was announced at a session of the Division of Sugar Chemistry and Technology of the American Chemical Society by Dr. Robert S. Aries, Professor of Chemical Engineering at the Polytechnic Institute of Brooklyn, and Haskell C. Needle, chemist, of R. S. Aries & Associates, New York firm of consulting engineers of which Dr. Aries is president. It involves the fermentation of blackstrap molasses. The first product, lactic acid, is a chemical which is widely used in food preparations. Lactic acid is reacted with methanol (wood alcohol), then with acetic acid, to form methyl acrylate, which is the plastic product.

Blackstrap molasses has been chosen as raw material, because of oversupply. Its price has slipped from a post-war high of 37 cents per gallon to 5 cents per gallon at the present time. Since every gallon of molasses contains six pounds of sugar, it can be obtained from this source at less than a cent per pound. Pure sugar could also be used, but would be much more expensive.

The fermentation and chemical process described by Dr. Aries and Mr. Needle would make two pounds of "synthetic glass" per gallon of molasses. Thus, from the current Cuban surplus of 50 million gallons of molasses, 100,000,000 pounds of unbreakable glass could be produced.

The lactic acid produced from molasses can also be used in other applications such as synthetic rubber, pharmaceuticals, acidulant in food products such as fruit essences, extracts, syrups, ice cream and baking powder; in dyeing of textiles, and curing of tobacco. It is now produced from more expensive sources, such as grains.

Raincoats for Structures

➤ DEVELOPMENT of a new plastic raincoat for protecting concrete structures and cement-asbestos pipe from erosion by water and acid soils was reported to the American Chemical Society.

Wartime shortages of cast iron and steel frequently necessitated substitution of cement-asbestos pipes and concrete water tanks, according to a paper by Charles M. Bodach and J. F. Wilkes of the Dearborn Chemical Company, Chicago.

Railroads found, however, that the demineralized water required for Diesel-electric locomotives rapidly dissolved the cement, with the result that the water was contaminated and the pipes and tanks failed.

Wax coatings, tried in the laboratory, protected the cement but made joints slippery, it was said, and so the search was started for another waterproofing material which would not be slippery.

The solution was a vinyl plastic raincoat. Cement-asbestos pipelines thus protected have now completed two years of service and are still as good as new. Tests show no measurable pickup of dissolved minerals in water standing in these lines for more than twelve hours.

Wrinkled Cotton, Shrunken Wool Scheduled to Disappear Soon

Textile Chemists Remake Fibers

► HAIRSPLITTING research revealing that individual cotton fibers are bundles of threadlets, each of which is only one two-millionth of an inch wide, has laid the foundation for better textiles and plastics, Dr. Charles W. Hock of the Hercules Powder Company, Wilmington, Del., reported to the national meeting of the American Chemical Society.

Natural cellulose occurs abundantly in nature, where it is a constituent of all vegetation, he explained. It is encountered, particularly, in such familiar staples of commerce as wood, cotton, ramie, and other fibers. Cotton, for example, is almost pure cellulose.

An understanding of the minute architecture of such fibers, especially in the range of dimensions visible only with the aid of microscopes, is of considerable practical importance in the efficient industrial utilization of this material. This holds true whether the cellulose is used directly, as in the construction of fabrics, or whether it is used as a chemical raw material for conversion to rayon and plastics.

A knowledge of the way in which cellulose fibers swell, split, and dissolve during degradative reactions is essential to their best utilization. Moreover, by ascertaining the nature of the structures into which cellulose can be broken down, we obtain a better understanding of the original structure of the fiber.

To the unaided eye a cotton fiber looks like a simple homogeneous filament. In reality, however, the structure of even so small an object as a single fiber is quite complex. When cellulose fibers are broken down they separate into long, fine, threadlike structures called fibrils. It is significant that regardless of how the degradation is brought about, whether it be caused by chemical agents such as acids and alkalies, by physical treatments such as grinding and vibration with high-frequency sound waves, or by the action of biological organisms such as molds and bacteria, the cellulose almost invariably breaks down into fibrils.

The finest of these are so narrow that they can be observed only at the high magnification obtainable with the electron microscope. It is estimated that it would require about two million fibrils, lying side by side, to extend one inch. Or, to put it another way, if a single fibril were increased to the diameter of a common lead pencil, a whole cotton fiber would, at the same magnification, be over ten yards wide. Just as a piece of sewing thread is made up of many individual cotton fibers, so is a single cotton fiber, in turn, made up of many fibrils.

The fibrils are relatively dense and impart to the fibers such properties as stiffness and tenacity. They are however poorly reactive toward chemical reagents. How dissimilarities in fibrillar patterns influence properties of the fibers is nicely illustrated by

ramie and cotton. Beside being three to four times broader than the fibrils in cotton, those in ramie are also considerably straighter and smoother. These dissimilarities in small-scale structure appear to account, in large measure, for the well-known differences in gross properties of these two types of fibers.

Ramie is a stiff, tough fiber which is relatively poorly reactive, while cotton is a comparatively weak, flexible fiber which is more reactive toward chemical reagents. This additional knowledge of the basic structure of fibrous materials should be helpful in using them to the fullest advantage in commercial applications.

Non-wrinkling Cotton

➤ WOMEN's cotton dresses that will not wrinkle or crease are promised by a discovery reported at the society's fall meeting by two Philadelphia chemists.

The discovery, which applies to rayon as well as cotton, is of potential significance to millions of American women, who spend countless hours each year ironing easily mussed dresses made of these fabrics.

The experiments in question showed that cotton and rayon can be made almost as crease-resistant as wool by treatment with certain chemicals containing formaldehyde, a compound widely used in the manufacture of plastics, according to D. D. Gagliardi and I. J. Grunfest of the Rohm & Haas Company.

By means of this treatment, the chemists declared, the range of usefulness of cotton and rayon fabrics is greatly extended. Shirt and suiting materials as well as dresses made from these fabrics can now be persuaded to hold their shape in much the same way as woolen goods.

When the problem of cotton and rayon creasing was first tackled, the report said, the properties of the individual fibers were closely examined and correlated with the properties of the fabrics. It was learned that cotton and rayon textiles muss easily because their fibers lack elasticity, and thus do not snap back into position when they are wrinkled.

Further research disclosed, however, that the elasticity of cotton and rayon can be improved with the aid of the formaldehyde chemicals, which are easily applied to fabrics during the finishing operations.

Compounds which are simply deposited on the fiber surface, as a sort of coating, do not improve crease resistance, but may actually cement the fibers together, producing stiffness, the paper asserted.

For a chemical to be effective in creaseproofing cotton and rayon materials, it must be able to penetrate each individual fiber and react with the cellulose. By chemically reacting with the celluose in the fibers, such compounds are permanently fixed so that the crease resistance imparted to the fabric is not easily removed by washing or dry cleaning.

This chemical modification of cotton and rayon fibers actually produces a new type of cellulose which is more elastic and more resilient.

Fire-Proof Fibers

➤ A NEW flame-retardant process for cotton and rayon fabrics which withstands repeated dry cleanings and normal home launderings without loss of flame-retardancy was described to the society by Dr. Hugh C. Gulledge

and Dr. George R. Seidel of the Pigments Department of E. I. du Pont de Nemours and Company, Newport, Del.

This new treatment represents a distinct improvement over previous flame-retardant processes, the Du Pont chemists told a symposium on "Flame Retarding of Textiles" held by the Society's Industrial and Engineering Division.

When properly applied it does not change the appearance, strength, draping qualities, or feel of the fabric, is not affected by exposure to rain and sunlight, and is not removed by dry cleaning and normal home laundering, they said. Furthermore, careful tests carried out by Du Pont's Medical Division show that fabrics given this new treatment have no irritating effect on the skin.

The treatment involves the application of a water solution of a titanium and antimony complex. These metallic salts appear to combine chemically with the cellulose molecules of cotton and rayon, rather than merely coat the fibers. Chemical reaction between cellulose and the titanium and antimony salts would account for the resistance of this new finish to washing and dry cleaning. While it has not yet been definitely established that the titanium and antimony react with the cellulose fibers, the durability of the finish imparted by this flame retardant, along with certain theoretical considerations, tends strongly to confirm the reaction theory.

All evidence to date suggests that the metal atoms are 'locked' into the molecular structure of the fibers, changing them chemically in such a way as to make them highly resistant to flaming, but causing little or no change in physical properties.

Since the treatment of fabrics with this solution of titanium and antimony salts demands carefully controlled conditions, it will be used only in textile finishing mills, and cannot be applied in homes or by laundering and dry-cleaning establishments.

The new development had its origin in a fundamental study of the chemistry of titanium in Du Pont laboratories. Although this metal is the ninth most abundant element in the earth's crust, its chemistry has been explored by only a few chemists specializing in this field. To date, virtually all of the titanium produced has been in the form of the white pigment, titanium dioxide, although recently Du Pont began the production of metallic titanium on a small commercial scale.

Early in their study of the basic chemistry of titanium, Du Pont chemists found that this element, in the form of titanyl sulfate, readily reacts with cellulose in the form of gel cellophane. They observed also that cotton cloth treated with titanium salts burned less readily than untreated fabric, but the degree of flame resistance was not practical. These observations nevertheless suggested that a durably flame-retardant finish might be developed based on titanium.

Combinations of titanium with other metallic salts were then tested. Some combinations showed a degree of flame-retardancy surpassing that of titanium alone. Of the many tried, however, antimony trichloride with titanyl chloride proved to be the most effective—a promising but altogether unexpected result. It was unexpected

because antimony oxide alone is ineffective and, furthermore, antimony oxide is completely removed by one household laundering. Yet the impregnation of cotton or rayon with titanyl chloride plus antimony chloride, followed by neutralization with an alkali, results in a durably flame-retardant fabric.

Wool Without Shrinking

▶ THE WORLD is entering the age of shrinkproof woolen clothing as a result of recent advances that enable wool to resist "felting," Dr. Milton Harris, head of the Harris Research Laboratories, Washington, D. C., reported.

Spurred on by the millions of dollars saved by reducing the shrinkage of Army socks, chemical research has now stopped many civilian wool garments from felting — a phenomenon in which the fibers become entangled in a tight, compact mass, causing excessive shrinkage under ordinary laundry conditions.

Sweaters, shirts, socks and other woolen clothing may now be readily laundered after they are adequately processed, according to Dr. Harris. Arnold Sookne and Herman Bogaty were co-authors of the paper presented before the A. C. S. Divisions of Colloid, Cellulose, and Physical and Inorganic Chemistry.

It can now be shown that three properties of wool fibers contribute to felting, the report said. First, the tendency of the fibers to bend or curl and thus become entangled under the influence of moisture, heat and mechanical working. Second, under the same conditions, the fibers are readily deformed — that is, stretched, twisted, or compressed — but recover from deformation. Third is the tendency of the wool fiber to migrate, or move in the fabric of yarn, much as a snake wriggles through the grass.

The last of these properties is apparently the most important single factor contributing to the felting process. Methods now available for controlling this tendency to migrate can reduce or completely eliminate the felting action. The cause of the migrating tendency apparently lies in the fact that wool fibers are covered with scales which overlap like shingles on a roof. Since the outer ends of the scales all point toward the fiber tip, they impart greater resistance to motion of the fiber in the direction of the tip than toward the root.

Most shrink-resistant processes act by altering one or more of these properties of curling, recovery from deformation, and migrating.

It is predicted that in the near future, all such wool items as socks, sweaters, knitting yarns, shirts, and blankets will be processed to make them readily and safely launderable.

In recent years much work has been done on the chemical modification of wool. Methods have been developed which involve the treatment of wool with chemicals which modify the sulfur cross-links of the amino acid cystine such that modified wools stable to alkalies, oxidizing and reducing agents are produced. On the other hand, wool can be modified by treatments which do not involve the sulfur cross-links. The reaction with formaldehyde under ordinary conditions results in such a type of modification.

Although the reactions of formaldehyde with synthetic protein fibers and

with wool have been known since 1903, it is only within recent years, in the case of synthetic protein fibers, that the reaction has achieved commercial importance. In fact no substitute for formaldehyde has yet been found, and the protein-formaldehyde reaction is a basic one in the preparation of synthetic protein filaments. On the other hand, the reaction of wool with formaldehyde has received relatively little study, and little or no commercial importance.

A study was made of the wool-formaldehyde reaction, and it was found that the product obtained is greatly influenced by experimental conditions. Under suitable conditions, treatment of wool with small amounts of neutral or slightly acidic formaldehyde produces a product which is more stable to alkali than is untreated wool. It is found that little reaction with cystine occurs, and other groups in the protein molecule are involved.

Compared to stabilized cross-links introduced in wool by methods previously described before the society, the formaldehyde linkage with wool is not too stable, substantial amounts being removed by boiling with acidic liquids. From an overall viewpoint, formaldehyde does to wool essentially what it does to synthetic protein fibers, but since wool has many cross-links in it originally, quantitatively, the effect is much less with wool. This is perhaps the reason that its use has not achieved any commercial importance in the woolen industry.

As more and more is learned about the modification reactions of wool by many chemical treatments, it is indicated that a number of treatments are available which stabilize wool against chemical attack encountered in certain uses. Of primary interest at present are the processes dependent on the treatment of wool with reducing agents in the presence of alkylating agents or other cross-linking agents. It is these processes which are achieving industrial importance.

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